NEW ZEALAND

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AS-NZS 1158-1-2 (2010) (English): Road lighting - Vehicular traffic (Category V) lighting - Guide to design, installation, operation and maintenance [By Authority of Main Roads Western Australia Guidelines]

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STANDARDS
NEW ZEALAND
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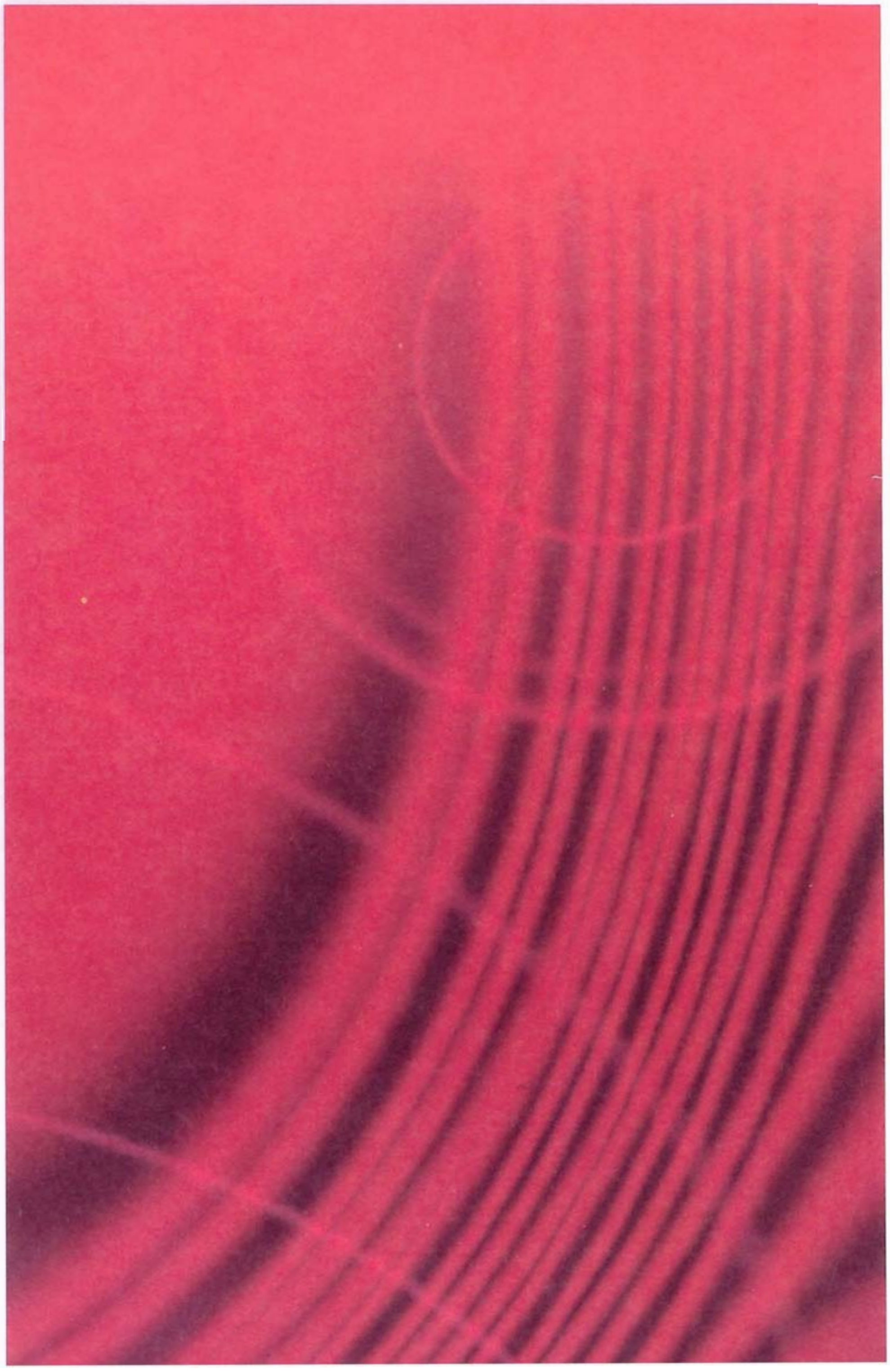
AS/NZS 1158.1.2:2010

Australian/New Zealand Standard™

Lighting for roads and public spaces

Part 1.2: Vehicular traffic (Category V) lighting—Guide to design, installation, operation and maintenance



STANDARDS
Australia

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Astronomical Society of Australia
Australian Industry Group
Australian Local Government Association
CIE Australia Inc.
Department of Transport and Main Roads, Queensland
Energy Networks Association
IES: The Lighting Society
Ingenium
Lighting Council Australia
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AS/NZS 1158.1.2:2010

Australian/New Zealand Standard™

Lighting for roads and public spaces

Part 1.2: Vehicular traffic (Category V) lighting—Guide to design, installation, operation and maintenance

Originated as AS/NZS 1158.1.3:1997.
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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee LG-002, Lighting for Roads and Public Spaces, to supersede AS/NZS 1158.1.3–1997 *Road Lighting* Part 1.3: *Vehicular traffic (Category V) lighting–Guide to design, installation, operation and maintenance*, now designated as Part 1.2.

This Standard is part of the AS/NZS 1158 series, *Lighting for roads and public spaces*, which covers lighting schemes for most roads and public spaces.

The performance criteria for such lighting schemes may include any or all of the following:

(a) Facilitation of safe movement.

(b) The discouragement of illegal acts.

(c) Contributing to the amenity of an area through increased aesthetic appeal.

The series has divided road lighting into the following two broad categories:

(i) *Category V lighting* Lighting that is applicable to roads on which the visual requirements of motorists are dominant, e.g. traffic routes.

(ii) *Category P lighting* Lighting that is applicable to roads on which the visual requirements of pedestrians are dominant, e.g. local roads and lighting that is applicable to outdoor public areas, other than roads, where the visual requirements of pedestrians are dominant, e.g. outdoor shopping precincts.

This Standard applies to Category V lighting.

Its objective is to provide guidance to those concerned with design, installation, operation and maintenance of such lighting, to facilitate compliance with the requirements of AS/NZS 1158.1.1.

The following Standards have been issued in the AS/NZS 1158 series:

AS/NZS		
1158	Lighting for roads and public spaces	
1158.0	Part 0:	Introduction
1158.1.1	Part 1.1:	Vehicular traffic (Category V) lighting—Performance and design requirements
1158.1.2	Part 1.2:	Vehicular traffic (Category V) lighting—Guide to design, installation, operation and maintenance (this Standard)
1158.2	Part 2:	Computer procedures for the calculation of light technical parameters for Category V and Category P lighting
1158.3.1	Part 3.1:	Pedestrian area (Category P) lighting—Performance and installation design requirements
1158.4	Part 4:	Lighting of pedestrian crossings
1158.5	Part 5:	Tunnels and underpasses
1158.6	Part 6:	Luminaires

Road lighting is acknowledged to be an effective crash counter-measure. The costs involved in providing road lighting can be demonstrated to provide significant financial and community benefits in terms of reductions in road crashes at night. Studies in Australia and New Zealand, and in other countries, have led to the conclusion that traffic route lighting is likely to reduce night time casualty crashes by about 30%, taken over the road network. A summary of the findings of lighting and crashes is given in Appendix C. (See also Ref. 9, 20 and 21 in Paragraph A2.)

The terms 'normative' and 'informative' have been used in this Standard to define the application of the appendix to which they apply. A 'normative' appendix is an integral part of a Standard, whereas an 'informative' appendix is only for information and guidance.

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FOREWORD

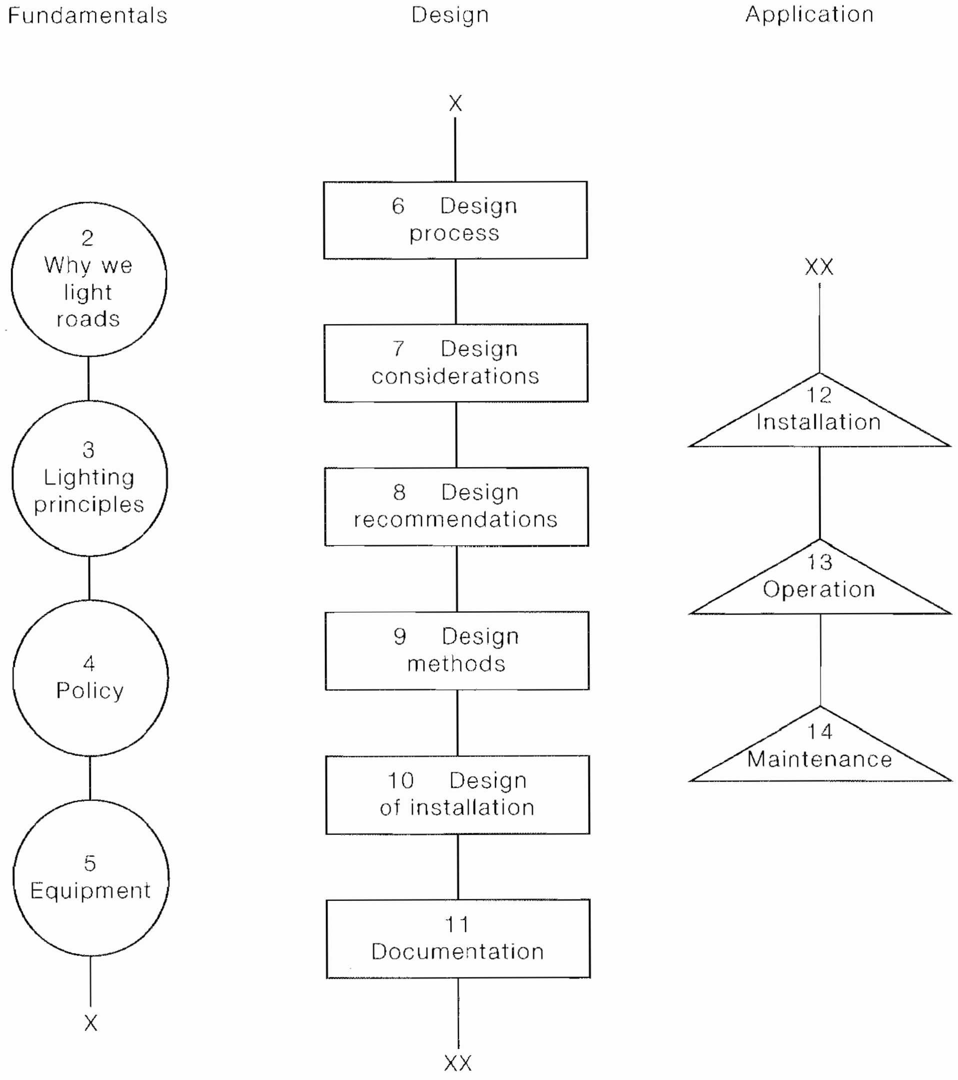
The subject matter covered in this Standard is divided into three main elements, as follows:

(a) *Fundamentals* The information that must be known before engaging in a road lighting design.

(b) *Design* The considerations and processes involved in the development of a design for a road lighting scheme.

(c) *Application* Advice relating to the installation, operation and maintenance of a road lighting scheme.

These three broad subject areas are further divided into sections within this Standard as shown in the flow chart below.



STANDARDS AUSTRALIA/STANDARDS NEW ZEALAND

Australian/New Zealand Standard
Lighting for roads and public spaces

Part 1.2: Vehicular traffic (Category V) lighting—Guide to design, installation, operation and maintenance

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard sets out requirements, background information, guidelines and other relevant information for the design, installation, operation and maintenance of Category V lighting schemes intended to comply with AS/NZS 1158.1.1. It should be read in conjunction with that Standard. For the purpose of this Standard, the lighting categories set out in AS/NZS 1158.1.1 apply. Table 2.1 of that Standard describes typical applications for each of the lighting categories given.

The Standard does not purport to cover every possible means of ensuring compliance with AS/NZS 1158.1.1.

Much of this Standard is also applicable to lighting schemes intended to comply with AS/NZS 1158.3.1 and reading of it in conjunction with that Standard is recommended.

The appropriate lighting category for a particular road is a matter for determination in consultation with the road or traffic authority concerned.

1.2 REFERENCED DOCUMENTS

A list of the Standards and other documents referred to in this Standard is given in Appendix A. The Appendix also lists a number of additional documents that are considered useful sources of information on the subject of this Standard.

1.3 DEFINITIONS

For the purpose of this Standard, the definitions given in AS/NZS 1158.0 apply.

NOTE: See Paragraph B3 of Appendix B for definitions of terms related to the use and placement of road lighting poles.

SECTION 2 WHY WE LIGHT ROADS

2.1 ROAD LIGHTING OBJECTIVES

The objective of road lighting is to provide an illuminated environment, which is conducive to the safe and comfortable movement of vehicular and pedestrian traffic at night, and the discouragement of illegal acts. To accomplish this, the lighting should reveal necessary visual information. This consists of the road itself, the course of the road ahead, kerbs, footpaths, property lines, road furniture and surface imperfections, together with the road users including pedestrians, cyclists and vehicles and their movements, and other animate and inanimate obstacles.

2.2 ROAD SAFETY

The primary purpose of road lighting is to protect people from injury and death on the roads at night. All efforts and technological developments harnessed to attain this goal will also help curb the economic toll that traffic crashes take on national resources. The lowering of crash costs alone will generally justify investment in optimized road lighting.

2.3 ROAD LIGHTING AS A CRASH COUNTERMEASURE

Road crashes at night are disproportionately higher in number and severity compared to daytime crashes. Individual factors such as increased alcohol usage, fatigue, and over-representation of young drivers in night traffic contribute to the problem. However, the major factor is darkness.

With the low light levels that prevail at night, visual capabilities such as acuity, distance judgement, speed of seeing, colour discrimination and glare tolerance are impaired. There will also be adverse interactions between impaired vision due to low light and other factors, such as inclement weather.

As a result of these conditions, visibility will be severely reduced at night. Thus, it can be expected that the provision of light through road lighting will be a crash countermeasure. However, the installation of the lighting cannot be expected to result in a reduction in crashes if there is a major traffic management or road design problem at any particular site.

The International Commission on Illumination (CIE) has conducted a review of research worldwide into the effectiveness of road lighting as a crash countermeasure. The findings are given in Ref. 4 in Paragraph A2 and in Appendix C.

2.4 SECURITY AND AMENITY

Further objectives of road lighting are to facilitate security and amenity. The provision of appropriate lighting can discourage crimes against both people and property, including parked vehicles. It may also enhance the environment for appropriate use by pedestrians and give rise to feelings/perceptions of safety and security.

SECTION 3 LIGHTING PRINCIPLES

3.1 VISUAL PROCESSES AND THE LIGHTING NEEDS OF ROAD USERS

Vehicle drivers require a readily discernible flow of visual information in order to safely, efficiently and comfortably carry out the task of driving. Some of this information is provided by traffic control signals, road signs or markings and by vehicle lighting, e.g. presence and brake lights and turn signals. However, much of the required information comes from the general road scene itself, e.g. from the run of the road ahead and its layout, the presence of vehicles and other road users, and their perceived speeds and manoeuvres.

Assimilation of this information is facilitated by the contrast of the objects of interest with their surrounds, by detail within the objects, and by colour and movement.

The capacity of the human visual system to assimilate information largely depends on the ambient light level. In daylight (unless dazzled by the sun) vision is optimal; contrast sensitivity, acuity, colour perception, motion perception and the speed of vision are all as good as is humanly possible.

In spite of the facility of the eye to adapt to changing light levels, optimum vision cannot be sustained at low light levels. The light level provided by a traffic route lighting installation should be sufficient to limit any deterioration of vision at night, so that the driver's vision is as near as practicable to the optimum. This is particularly important on traffic routes where an error in judgement could result in a severe crash. If the lighting is sufficient for drivers of vehicles, it will be more than adequate for other more slow-moving road users, such as pedestrians and cyclists.

The values of luminance and illuminance specified in Section 2 of AS/NZS 1158.1.1 are pitched so the human visual system is on the borderline between being light-adapted (photopic vision) and of starting to become dark-adapted (mesopic vision). The values specified are much greater than those pertaining to the completely dark-adapted eyes (scotopic vision). If completely dark-adapted, e.g. to a moonless night, the eye would only have the facility to detect very large moving shapes, without any colour or detail being discernible. However, the lighting levels specified for traffic route lighting, whilst maintaining vision at close to the optimum, are modest and will only be a fraction of those applying under daylight. Light levels experienced in daylight will generally be a thousand times higher, and even on dull days, a hundred times higher. Again, by comparison, office lighting will be more than 10 times the level implicit in traffic route lighting. The success of road lighting as a traffic crash counter measure indicates that this lighting level is both sufficient and necessary (see Clause 2.3 and Appendix C).

3.2 LIGHTING INSTALLATIONS AND LIGHT TECHNICAL PARAMETERS

3.2.1 Basis of road lighting

Once the general level of lighting that is required has been established, the purpose of the light, as well as the light technical parameters needed to achieve that purpose, should be considered.

The carriageway of the traffic route is particularly important, in that this is the area of most activity and of the fastest activity. Moreover, the carriageway will have a surface of reasonably predictable and stable reflection characteristics. This allows the lighting of the carriageway to be designed on the basis of the luminance of the road surface, which is appropriate, since it is the luminance (or 'brightness') of that surface that is seen and not the illuminance (or quantity of light) falling on it.

Making the road surface bright by exploiting its reflection characteristics has the effect of—

(a) raising the adaption light level of the driver and, by so doing, maintaining general visual performance at near optimum;

(b) emphasizing the condition and run of the road ahead;

(c) providing an extended luminous background, which provides a frame of reference in judging (subconsciously) relative speed and movement; and

(d) facilitating visibility of the presence and shape of objects on the carriageway by silhouette, i.e. dark object against bright surrounds.

In order to make the road surface bright, a luminaire emits light in a beam directed towards the oncoming driver. With this beam direction there is no light on the object surfaces facing the driver. Hence the possibility of viewing objects by silhouette as described in Item (d) above. The effect is most apparent when objects are some distance away (several spans of lighting ahead) and are thus, angularly, relatively small.

The luminaire will also have a trailing beam emitting light in the direction of travel. This light will directly illuminate objects to show up colour and detail. The effect is most apparent when the objects are close and are thus relatively large, in angular size.

Of course, for drivers travelling in the opposite direction, the two beams of light are in effect, reversed. The one luminaire thus serves both directions of travel.

3.2.2 Light technical parameters

Section 2 of AS/NZS 1158.1.1 specifies maintained (minimum) values for the average carriageway luminance ($\overline{L}$) which is the simple arithmetic mean of luminances within a span of lighting*. Maintained values for $\overline{L}$ are specified to ensure an adequate level of carriageway luminance on the initial installation of the lighting and to limit the subsequent deterioration in service to a tolerable level. Several lighting categories are given to cover the range of traffic routes with respect to the amount and type of activity on them (see Section 1 of AS/NZS 1158.1.1).

In specifying maintained values for $\overline{L}$, a limitation is placed on the uniformity of luminance to ensure the following:

(a) That there are no dark areas within a span of lighting, which may conceal objects. The light technical parameter is U_O and is a ratio, i.e. $U_O = L_{min} \div \overline{L}$. The specified value is the same for each lighting category since it effectively limits the minimum luminance (L_{min}) anywhere within a span of lighting.

(b) That there are no light and dark bars across the road, repeated through the length of the installation. This may arise, for example, if luminaires with excellent glare control are spaced excessively far apart. The light technical parameter is U_L and is a ratio, i.e. $U_L = L_{min} \div L_{max}$. The specified value applies along a designated longitudinal line within a span of lighting and, being a ratio, is the same for each lighting sub-category.

A traffic route will consist of a variety of elements other than the straight carriageway. For example, there are the intersections and the immediate surrounds to the carriageway edges, i.e. the verges. These areas do not lend themselves to a luminance-based lighting design.

For intersections, the carriageway may not be visible ahead when undertaking turning manoeuvres. It is therefore important to illuminate channelizations, road surface markings and vehicles within the general area of the intersection.

---

* The exact definitions of the light technical parameters are given in AS/NZS 1158.0.

For this purpose, a maintained (minimum) illuminance (E_{Ph}) at any point within the designated area is specified. Maintained values of E_{Ph} are given, together with different values for each lighting category reflecting the level and type of activity on the road. Thus E_{Ph} sets the general level of lighting required. The uniformity of illuminance is controlled to ensure there are no excessively bright points within the designated design area. The light technical parameter is U_{E1} and is a ratio, i.e. $U_{\mathrm{E1}} = E_{\mathrm{max}} \div E_{\mathrm{Ph}}$. As the uniformity is a ratio, only one value is given for all the lighting sub categories.

For road verges, the surface will be indeterminate, i.e. shoulder, footpath, nature strip. Nevertheless such surfaces are important as a starting point for pedestrians to cross the carriageway. In these cases, the lighting design is based on the illuminance on the relevant surface. The illumination of the verges is ensured by specifying that the illuminance on the designated verge area be not less than a specified fraction of the value for U_{E1} that applies for the contiguous carriageway area. The light technical parameter is E_s.

Glare from the luminaires has the potential to inhibit vision. Glare is conventionally categorized into that which gives rise to an impairment in seeing (disability glare) and that which gives rise to visual discomfort (discomfort glare). In road lighting, attention is specifically given to the former on the basis that, if disability glare is suitably controlled, the discomfort glare will be controlled as well. The relevant light technical parameter is *TI*. One maximum value is given for all lighting categories.

It should be noted that glare control and the production of carriageway surface luminance are not independent of one another. The specified value of *TI* is a compromise between adequate glare control and economic spacing of the luminaires. Excellent glare control will necessitate the use of luminaires with a much lower value of *TI* ($\approx$10%). However, the resulting reduced angle of the beam of light from the luminaire downward vertical will require a concomitant closer spacing of the luminaires. The use of such luminaires will normally be restricted to situations where good glare control is necessary, e.g. on bridges where luminaires may be seen against dark backgrounds, around airports, and in other locations where a high degree of glare control is required. (See also Clause 5.3.)

The glare from vehicle headlights is controlled by specified limits in the relevant (motor vehicle) Australian Design Rules and in New Zealand the Land Transport Rule Vehicle Lighting 2004.

The environmental effects of installing road lighting also need to be considered. These are described in Clause 1.1. The upward waste light ratio (*UWLR*) is the only light technical parameter specified in Section 2 of AS/NZS 1158.1.1 and controls the amount of light that road lighting luminaires may release above the horizontal.

3.3 FACTORS AFFECTING PAVEMENT LUMINANCE

A road lighting luminaire mounted above the pavement produces a characteristic 'T' shaped bright patch on the road surface. It comprises a wide head stretching across the road, commencing a very short distance behind the luminaire, with a tail extending in the direction of the observer towards the image point (see Figure 3.1).

The actual shape will depend partly on the light distribution from the luminaire and partly on the type of road surface. A well-lit road is judged to be one that looks evenly bright, and to achieve this, the 'T' patches of brightness from each luminaire should interlock rather like the pattern of a jigsaw (see Figure 3.2).

The luminance of a point on the pavement is principally influenced by the amount of light incident at the point in question, the angles of incidence and of observation, and the reflecting characteristics of the pavement surface. The parameters involved are illustrated in Figure 3.3.

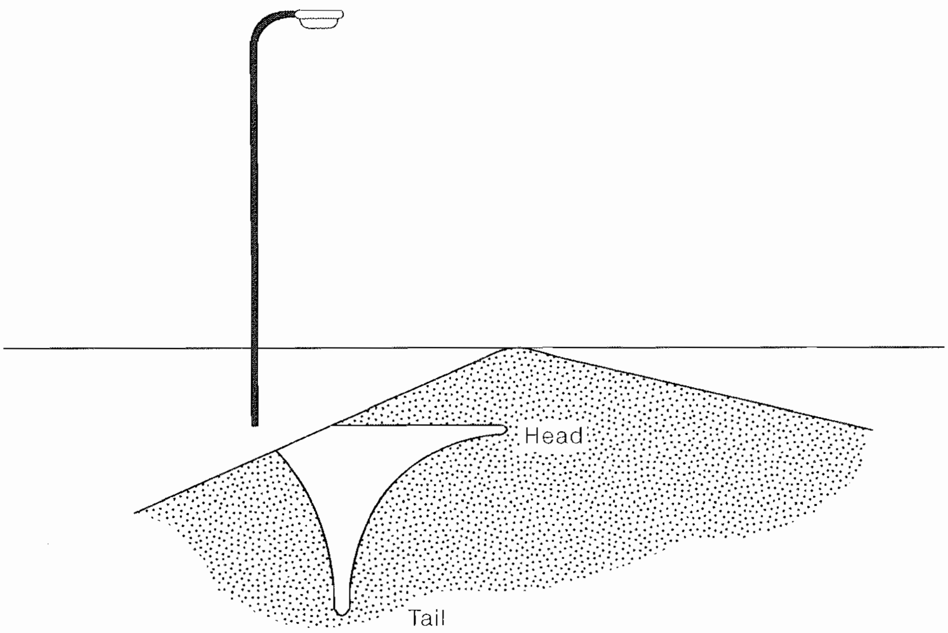
The illuminance (E), or the amount of light incident on the horizontal surface, in lux, at a given point (P) may be calculated from the following equation:

$$E = \frac{I \cos^3 \gamma}{H^2} \qquad \text{. . . 3.3(1)}$$

Part of this light is reflected in the direction of the observers' eye and it is this component that creates the sense of brightness or luminance of the surface. The luminance (L), in candelas per square metre, in the direction of observation, is given by the following equation:

$$L = \frac{I\, q \cos^3 \gamma}{H^2} \qquad \text{. . . 3.3(2)}$$

Where q is the luminance coefficient for the surface at the point, which varies with the angles alpha (a), beta (b) and gamma (g) as defined in Figure 3.3 and with the surface characteristics as discussed in Clause 3.4 (see Ref. 20 in Paragraph A2).



NOTE: The tail of the light patch always extends towards the observer.

FIGURE 3.1 CHARACTERISTIC 'T' SHAPED LIGHT DISTRIBUTION FROM A SINGLE LUMINAIRE

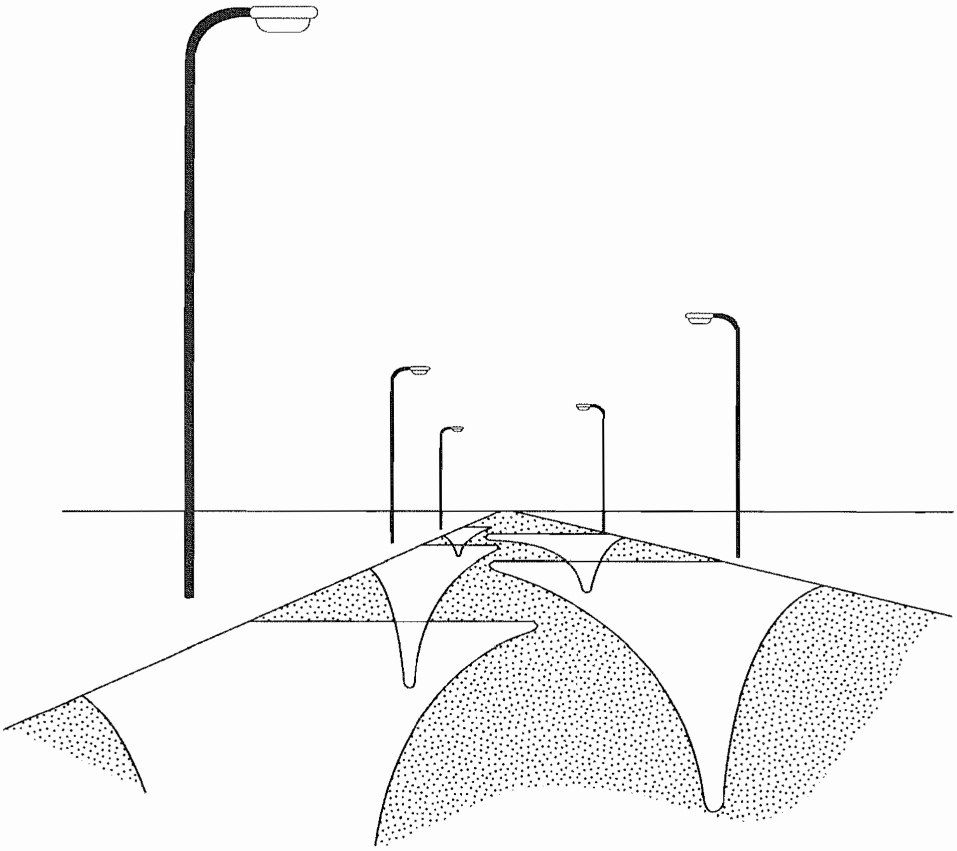
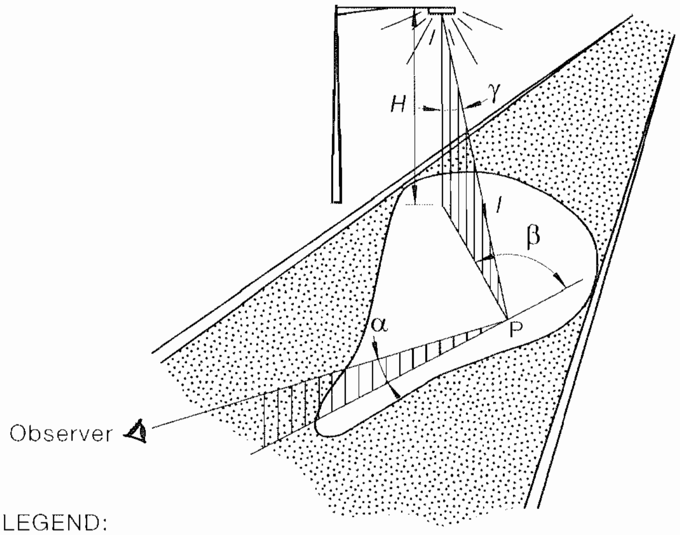


FIGURE 3.2 TYPICAL LIGHTING INSTALLATION WITH INTERLOCKING OF ‘T’ SHAPED LIGHT DISTRIBUTIONS



LEGEND:

I = luminous intensity of the light source directed toward P, in cd/m^2
α = angle of observation (usually taken as 1°)
β = angle between the planes of the direction of illumination and the direction of observation at the point P
γ = vertical angle of intensity
H = mounting height of the light source, in metres

FIGURE 3.3 PARAMETERS AFFECTING PAVEMENT LUMINANCE

3.4 PAVEMENT REFLECTANCE

3.4.1 General

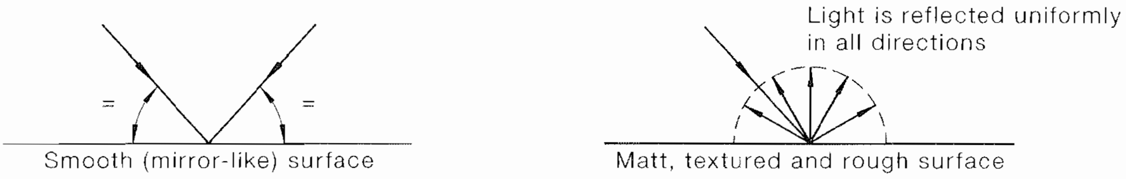
When light is beamed onto a surface, it is reflected as a specular reflection, if the surface is mirror-like, or as diffuse reflection, if the surface is completely matt, textured and rough. In practice, road surfaces exhibit both of these modes of reflection resulting in preferential reflection towards the eye of the vehicle driver. This is illustrated in simplified terms in Figure 3.4.

The reflecting properties of the road surface play an important part in the performance achieved by a road lighting installation. The reflecting characteristics of a road pavement surface, which influences the luminance coefficient (q), depends on the following:

(a) The macro and micro texture (i.e. whether it is rough or smooth, harsh or polished).

(b) The colour and lightness of the road material.

(c) The degree of dampness of the surface.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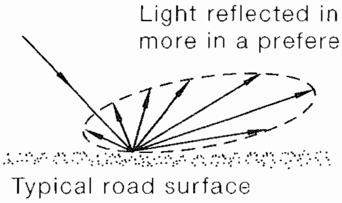
Smooth (mirror-like) surface
Light is reflected uniformly
in all directions
Matt, textured and rough surface

(a) Specular reflection

(b) Diffuse reflection


Light reflected in all directions but
more in a preferential direction
Typical road surface

(c) Preferential reflection

NOTES: A road pavement exhibits a combination of specular and diffuse reflection, resulting in preferential reflection towards the eye of the vehicle driver.

FIGURE 3.4 PAVEMENT REFLECTION

3.4.2 Surface texture

Surface texture is very important to road lighting performance, and also influences skid resistance and other traffic characteristics, such as noise. In respect to lighting, coarse-textured surfaces produce more diffuse reflection of light, which results in more rounded (i.e. shorter) light patches from individual luminaires. This requires a closer spacing of luminaires to achieve a given average luminance and uniformity (see Figure 3.5).

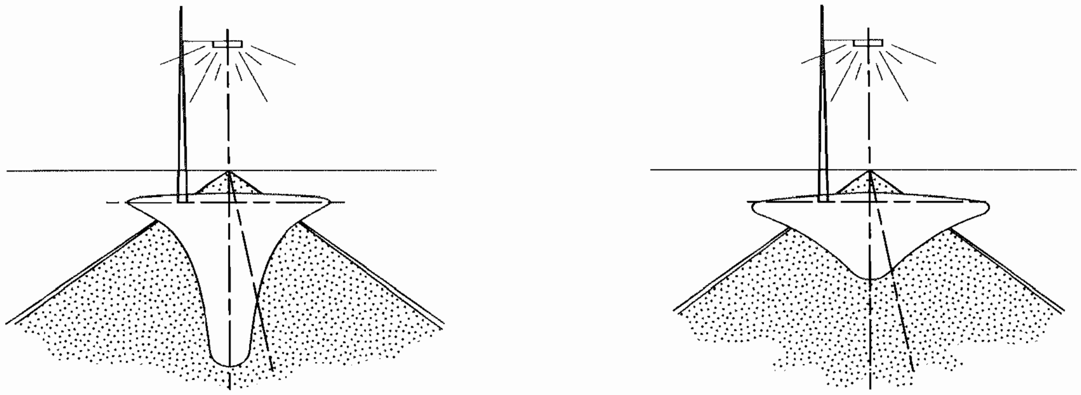
Polishing of the surface has the effect of reducing surface micro texture. This slightly increases the specular reflecting properties, thus increasing the light reflected in the preferential direction, resulting in longer light patches and possible improved uniformity of lighting on dry pavements.

3.4.3 Colour and lightness

While the actual colour of the surface plays only a minimal role, the lightness (especially where artificial brighteners are used) can significantly increase the luminance coefficient and thus the average luminance.

The variation of colour, lightness and surface texture are represented in several standard road surfaces defined in CIE Publication No. 30.2. The classification adopted in that publication is summarized in Table 3.1.

See Clause 7.6 for details of the standard road surfaces that are assumed in AS/NZS 1158.1.1 for calculations of the light technical parameters.



(a) Smooth textured surface, e.g. R3, R4, and NZN4

(b) Rough textured surface, e.g. R1, R2 and NZR2

FIGURE 3.5 EFFECT OF SURFACE TEXTURE IN FIGURE 3.5(B) NZR2

TABLE 3.1

CLASSIFICATIONS OF ROAD SURFACES FOR LUMINANCE CALCULATIONS

Class	Description
R1*	(a) Asphaltic road surfaces with at least 15% of artificial brightener or with at least 30% of very bright anorthosites (arclyte, labradorite or similar). (b) Surface dressings with chippings where over 80% of the road surface is covered and where chippings exist for a great many artificial brighteners or for 100% of very bright anorthosites. (c) Concrete road surfaces.
R2* and NZR2†	(a) Surface dressings with harsh texture and with normal aggregates (b) Asphaltic surface with 10% to 15% of artificial brighteners in the mixture (c) Coarse and harsh asphaltic concrete rich in gravel (>60%) and with gravel sizes up to or greater than 10 mm. (d) Mastic asphalt (Gussasphalt) after dressing in new condition
R3*	(a) Asphaltic concrete (cold, mastic asphalt) with gravel sizes up to 10 mm but with harsh texture (sandpaper). (b) Surface dressings with coarse texture but polished.
R4* and NZN4†	(a) Mastic asphalt (Gussasphalt) after some months of use. (b) Road surfaces with rather smooth or polished texture.

* Characteristics defined in CIE Publication No 30.2.

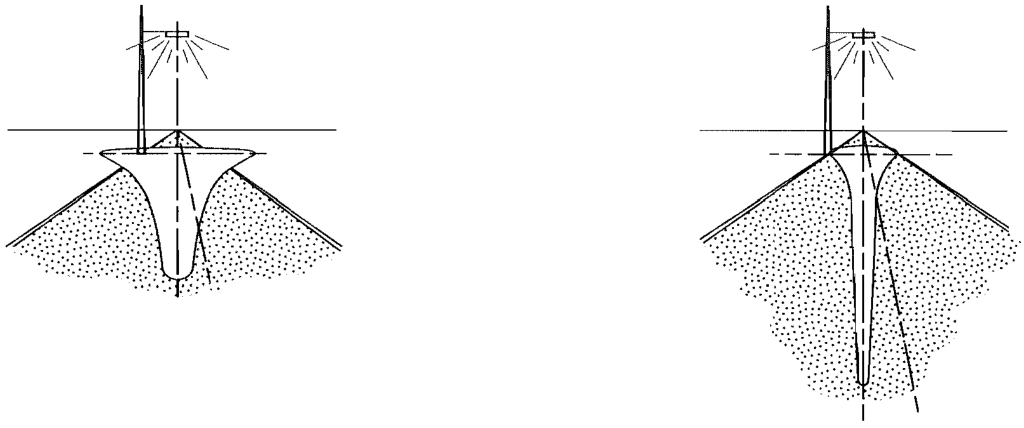
† Characteristics defined in Appendix D of AS/NZS 1158.2. Same as corresponding CIE surfaces but with a multiplication factor applied to the luminance coefficient (q).

3.4.4 Wet pavements

The degree of wetness or dryness of the pavement surface has a marked effect on the performance of road lighting. As a normal pavement changes progressively from a dry state to become damp, then wet and ultimately inundated, the reflecting characteristics change from diffuse reflection, becoming increasingly specular to the point where the surface of the water film reflects like a mirror. During this change, the size and shape of the light patches formed by the luminaires initially become larger (when the surface is just slightly damp) thereby improving both the level of luminance and uniformity. As further wetness develops, the light patches become narrower, elongated and brighter (as specular reflection increases), until ultimately the light from each luminaire is reflected as intense bands of light with the width and luminance approximately that of the actual luminaire (see Figure 3.6).

Increasing the coarseness or texture depth of a road pavement surface enhances the ability of the surface to maintain uniformity of lighting under damp to wet conditions. It may be noted that coarse textured pavements also improve skid resistance in wet conditions and reduce the amount of spray thrown up by tyres from a wet road. A classification of wet surfaces, including standard tabulations of reflection data for each surface, is given in CIE Publication No. 47.

The performance of a lighting installation under wet conditions depends largely on the characteristics of the road pavement over which the lighting designer has no control. No light technical parameters are therefore specified for wet road conditions but advice is given on measures that can be taken to enhance visibility (see Clause 7.5.2).



(a) Dry Surface

(b) Wet surface

FIGURE 3.6 EFFECT OF PAVEMENT WETNESS

SECTION 4 POLICY CONSIDERATIONS

Generally the road controlling authority will be the owner/operator of the road that lighting is installed on. The responsibility of defining which road elements require lighting falls upon this body. While designers can offer advice on the level of lighting that may be required for Category V road lighting schemes as set out in AS/NZS 1158.1.1, Table 2.1, the warrants are set by the road authority.

Most road controlling authorities have their own policy and standards for road lighting that must be adhered to.

SECTION 5 EQUIPMENT

5.1 GENERAL

Road lighting equipment involves three main items, as follows:

(a) *Lamps* The replaceable unit that is the source of the light.

(b) *Luminaires* The apparatus housing the lamp and controlling the light distribution.

(c) *Bracket arms and poles* The structural members that mount the luminaire(s) via a bracket arm to the vertical support structure.

Other equipment includes luminaire control gear, terminal panels, pole cages, pits, ducting, electrical cables and junction boxes. While these are important elements of lighting equipment, they will not be discussed in this Standard. Detailed information can be obtained from the relevant authority/agency.

5.2 LAMPS

The following high intensity discharge (HID) lamps shall be used for the provision of Category V lighting, as set out in AS/NZS 1158.1.1, Clause 2.8:

(a) High pressure sodium vapour lamps with clear or diffusing outer envelopes.

(b) Metal halide lamps with clear or diffusing outer envelopes.

A comparison of the main characteristics of the above lamps is given in Table 5.1.

5.3 ROAD LIGHTING LUMINAIRES

Luminaires may have either integral or remote control equipment. Requirements for road lighting luminaires are as specified in AS/NZS 1158.6.

Luminaires are available with either dished bowl or flat (aeroscreen) visors.

The dished bowl visor types are designed to allow a higher light output at angles nearer to horizontal than the flat (aeroscreen) visor types. The former provide substantially increased spacing compared with the flat (aeroscreen) visor types and consequently are the most commonly utilized luminaires. However, these luminaires exhibit higher glare than the flat (aeroscreen) visor types.

The flat (aeroscreen) visor types, whilst normally providing a higher quality installation, may only be justified where a greater degree of glare control is deemed necessary, since these luminaires generally require closer spacings than those for dished bowl luminaires. The following are typical examples of these installations:

(a) To satisfy the requirements of the civil aviation authority, in areas surrounding airports.

(b) To reduce spill light onto properties abutting roads that require Category V lighting, e.g. residential properties adjacent to freeways.

(c) To reduce glare at locations where the background is intrinsically dark, e.g. bridges, flyovers, overpasses, isolated intersections.

TABLE 5.1

COMPARISON OF DISCHARGE LAMPS USED FOR CATEGORY V LIGHTING

1	2	3	4	5	6	7
Lamp type	**Approx. average luminous efficacy (see Notes) (lm/W)**	**Typical average useful life (see Notes) (h)**	**Commonly used ratings (W)**	**Source appearance**	**Colour rendering**	**Comments**
High Pressure Sodium Vapour	120	18 000	100 150 250 400	Golden yellow	Fair	Most cost-effective light source due to high efficiency, long life and high lumen maintenance. To be used for general Category V lighting.
Metal Halide Ceramic	105	8 000	100 150 250 400	White or warm white	Excellent	May be used for high prestige areas. Not favoured for general use on overall economic grounds. Offers better efficacy and lower early failure rate performance and life than Quartz lamps.
Metal Halide Quartz	80	8 000	100 150 250 400	White or warm white	Good	Not favoured for general use on overall economic grounds. Some variations in colour appearance may be observed between individual lamps.

NOTES:

1 The data given in Columns 2 and 3 are only indicative. See Appendix E for typical lamp mortality and lumen depreciation data, which should be considered in conjunction with the data of Columns 2 and 3. Significant variations in this data may apply for different lamp ratings and for lamps of the same rating produced by different manufacturers.

2 For design purposes, data applicable to the selected lamp type and rating should be obtained from the lamp supplier.

5.4 BRACKET ARMS AND POLES

5.4.1 Dimensions

Preferred dimensions of lighting poles and bracket arms used for the mounting of road lighting luminaires are given in AS 1798.

5.4.2 Pole types

Consideration should be given to the type of pole used and its installation requirements (see Clause 7.2) as follows:

(a) *Material* The pole may be manufactured from a variety of materials including metal (generally galvanized steel), fibreglass, concrete or timber.

(b) *Installation* The method of installation can be—

   (i) direct-buried; or

   (ii) baseplate-mounted.

(c) *Power supply* The method of supply of power to a pole depends on the type of pole. Power supply for rigid poles may be aerial or underground but for frangible poles it is required to be underground. Slip base type frangible poles are required to be fitted with a special plug and socket connector located in the pole base. For the energy (impact) absorbing type refer to the relevant road lighting owner for connection arrangements.

(d) *Maintenance* Account should be taken of necessary provision for access to lighting equipment for maintenance.

Sound traffic engineering and safety principles should be employed in the selection of the correct type of pole for the task at hand.

NOTE: See Appendix B for guidelines on the use and placement of rigid and frangible road lighting poles.

5.4.3 Combination traffic signal mast arm and joint-use road lighting poles

Combination mast arm and joint-use poles in accordance with AS 2979 should be used when lighting intersections and junctions at which traffic signals are proposed or installed. This will enable the road lighting luminaires to be accommodated on the proposed/existing road traffic signals hardware, resulting in a safer and more economical installation. In addition it may be easier to meet the lighting design requirements at larger intersections and junctions.

Conversely, when designing new traffic signal installations, it is important that current and known future requirements for road lighting be considered so that, where possible, road traffic signals and lighting can share the same pole.

SECTION 6 DESIGN PROCESS

6.1 GENERAL

Road lighting design requires more than just putting luminaires on poles. It involves a design process addressing sound traffic engineering principles and safety.

AS/NZS 1158, Part 1.1, Appendix C sets out the minimum technical information that should be provided to the designer of a Category V road lighting scheme. This Section amplifies this and fully details the design process. The design process commences with the provision of a detailed design brief from the client containing all the relevant design information. By necessity there will often be consultation between the client and the road lighting designer concerning design parameters and site conditions, for example, in the determination of the carriageway lighting design width. However, the final decisions are the responsibility of the client.

6.2 BASES OF ROAD LIGHTING PROCESS

The bases of the provision, design and operation of a road lighting scheme is as follows:

(a) Background information (see Sections 2 and 3).

(b) Authority (see Section 4).

(c) Preliminary design information (see Sections 5 and 7).

(d) Road lighting design (see Sections 8, 9 and 10).

(e) Documentation (see Section 11).

(f) Installation (see Section 12).

(g) Operation (see Section 13).

(h) Maintenance (see Section 14).

6.3 SIMPLIFIED LIGHTING DESIGN PROCESS

The following sets out the simplified steps in the lighting design process and also serves as a brief specifying requirements for the provision of a lighting design service, including a statement of the scope of work that the consultant/contractor is required to carry out:

(a) Hold discussions with the client regarding their specific design parameters.

(b) Obtain relevant cadastral and civil layout plans from the relevant authorities, if available.

(c) Perform site inspections and surveys to mark/confirm all pole locations, luminaire types and lamp ratings, length of outreach brackets and mounting heights, overhead conductor clearances, road geometries and details of road channelization.

(d) Undertake designs to comply with AS/NZS 1158.1.1 and other special requirements that apply.

(e) Prepare the design using the relevant I-tables from the luminaire manufacturers.

(f) Prepare plans and works schedules giving details of luminaires, their locations, mounting heights and details of brackets. Include details of additional poles to be installed and agreed alterations to the utility services to accommodate the lighting scheme.

(g) Nominate luminaires that comply with AS/NZS 1158.6.

(h) Submit design calculations complying with AS/NZS 1158.1.1, and proposed road lighting arrangement drawings.

(i) Ensure the final designs have been signed as recommended and approved by persons with qualifications recognized by the client and satisfying any statutory requirements.

(j) Submit completed documentation, including computer-generated drawings.

(k) Liaise with construction staff, if requested, during the construction works scheduling or lighting installation stage.

6.4 FULL ROAD LIGHTING DESIGN PROCESS

6.4.1 Steps involved in process

The full road lighting design process will involve all or most of the steps illustrated in Appendix D, which are described here and in Sections 7 to 11.

6.4.2 Design brief checklist

The design brief should contain all the relevant information required for a specific project. This may include some or all of the following:

(a) Brief description of work(s).

(b) Lighting categories, including those of intersecting roads.

(c) Overall site plan(s) showing a line view of the project, including features such as intersections, junctions, roundabouts, on/off ramps, bridges, overpasses at grade separation and road names.

(d) Accurate base plan(s) to a nominated scale, preferably showing only the following:

    (i) Road features, e.g. lanes, shoulders, medians.

    (ii) Details of any traffic signals.

    (iii) All radii of curvature of route lighting segments and on/off ramps.

    (iv) Control lines with identifying names.

    (v) Chainages.

    (vi) Roadside features, e.g. cut, fill, trees, drainage.

    (vii) Electricity authority details, e.g. poles, overhead power supplies and existing lighting.

    (viii) Relevant underground ducting or services.

    (ix) Clear start/cut-off points where plans overlap.

(e) Extent of the road lighting required, including nominated chainages.

(f) Cross-section plan(s).

(g) Anticipated electricity authority lighting tariff(s).

(h) Any special equipment requirements, e.g. aeroscreen luminaires.

(i) Relevant road authority policies on equipment and pole placement.

(j) Any regulatory limitations, e.g. civil aviation, marine and railway.

(k) Identification of observatories.

(l) Clear indication of areas where lighting structures are not permissible.

(m) Identification of areas of civic, historical, or special significance.

(n) AADT of major and minor roads.

(o) Project engineer's name and contact number.

(p) Name of local authority.

(q) Name of electricity supply authority.

(r) Project identification number.

(s) Required by date.

(t) Estimate costing type, e.g. unit rate.

6.4.3 Site inspection check list

A site inspection should be performed to verify the relevant site details that may influence the road lighting design, particularly pole positions, as follows:

(a) Record location and type of existing road lighting poles and distribution poles and their pole numbers.

(b) Location of proposed new road lighting pole(s).

(c) Location of proposed new outreach arm(s).

(d) Location of proposed new ducting and overhead catenary lines.

(e) Clearance to obstacles, e.g. power lines and trees.

It is important that the road lighting allocation in the road reserve is identified as well as whether or not there is an alternative allocation that can be used, if necessary, so that poles can be positioned as far from the edge of the traffic lane(s) as possible, e.g. on the property line.

SECTION 7 DESIGN CONSIDERATIONS

7.1 GENERAL

To be effective, Category V road lighting should provide a level of visibility that enables the motorist to see quickly, distinctly and with a degree of certainty all significant detail, most notably the alignment of the road (its direction and its surrounds). Uniformity in relation to light levels and pole placement is essential so as not to cause indecision and confusion.

When designing Category V lighting, the lighting designer should call upon traffic engineering input to optimize lighting designs taking into account road lighting parameters, lighting poles, luminaires, road safety, site geometry, economics, maintenance and aesthetics.

7.2 ROAD SAFETY CONSIDERATIONS

7.2.1 General

Road lighting is provided, in addition to other traffic control devices, to improve road safety during hours of darkness. The designer should ensure the provision of road lighting does not detract from the existing level of road safety. Consideration should be given to the relevant road authority policies on lighting levels and the location and use of road lighting poles.

Where economically viable, consideration should be given to the use of existing structures, or new structures with combined functions, to support lighting equipment in order to reduce the number of roadside hazards. Typical examples are as follows:

(a) Joint-use pole for the support of luminaires and traffic signals.

(b) Combination traffic signal mast arm with lighting outreach arm assembly.

(c) Joint-use pole for road lighting and electricity distribution, telecommunications or tramway services.

(d) Other structures such as building walls or verandas.

7.2.2 Pole positions

Road safety will be enhanced by locating lighting poles in positions that are unlikely to cause a hazard to errant vehicles. If it is not possible to satisfy this objective, then consideration should be given to the use of frangible pole types. In determining the location and type of pole, consideration should be given to the following and Appendix B:

(a) Speed zones.

(b) Traffic volumes.

(c) Traversable and non-traversable verges.

(d) Clear zones, narrow, unprotected traffic islands and medians.

(e) Obstructions on the side of the road, e.g. services, trees and road furniture.

(f) Presence of crash barrier and clearance to them.

(g) Locations where the fall of the pole may foul overhead electrical conductors.

(h) Low-lying areas where drainage is poor.

(i) Accessibility to luminaires for maintenance purposes, e.g. provision for service vehicle access, clearances from overhead conductors.

(j) Parking or other low speed activity that may result in crash damage to the poles.

(k) Level of pedestrian activity.

7.2.3 Pole setback and pole types

The early research by Fox, Good and Joubert (see Ref. 10 in Paragraph A2) into crashes on urban roads established that a factor affecting the likelihood of a vehicle that had left the carriageway colliding with a utility pole was the distance between the pole and the edge of the carriageway. For lighting poles this distance is known as the pole setback and the research shows that as the setback increases the likelihood of a crash decreases. Further crash data show that for rigid poles the severity of such crashes is disproportionately great. Therefore rigid lighting poles should be positioned with as great a set back as possible and be positioned against the property line in urban areas and for all other locations as far from the edge of the carriageway as is practicable. Increased pole setback can be accommodated by a corresponding increase in outreach to maintain lighting design requirements.

Since that research, frangible poles have been developed. These greatly reduce vehicle damage and the trauma to occupants by reducing violent deceleration on impact and do not require a very large pole setback (see Ref. 1 in Paragraph A2). These can be employed effectively on higher speed roads and where pedestrian traffic is low.

Selection of an appropriate pole type and setback commensurate with the traffic hazard will result in the safest possible lighting installation. Recommended minimum setbacks and pole exclusion zones from the kerb for various traffic conditions and pole type are set out in Appendix B.

7.2.4 Curves

Curves may be lit from poles positioned on the inside, the outside or in some combination of this, depending on (amongst other factors) the road width.

Locating poles on the outside of curves provides additional visual guidance through the curve, and fewer poles will be required to achieve the required lighting level. Locating poles on the inside of curves places the poles in a less vulnerable position and reduces the chances of their being struck by errant vehicles.

The decision of where to locate poles will be dependent on the pole type (see Appendix B) and the parameters of the lighting design.

7.2.5 Roundabouts

The satisfactory operation of a roundabout relies heavily on the ability of drivers to enter into and separate from a circulating traffic stream in a safe and efficient manner.

For details of the pole placement with respect to the size and layout of a roundabout see Clause 8.6 and Appendix B.

7.2.6 Delineation

Where possible, luminaires and poles should provide a clear and continuous line, delineating the course of the road ahead. At complicated locations care should be taken to position the luminaires so motorists are not presented with a misleading view.

NOTE: See Figure F14, Appendix F, for an example of a misleading array of luminaires.

7.2.7 Joint-use traffic signal mast arms and joint-use lighting poles

The use of joint-use traffic signal mast arms and joint-use lighting poles at signalized intersections and junctions will minimize the number of potential hazards placed adjacent to the roadway and may also provide the driver with a clearer view of the road situation, highlighting the location of traffic signals and the course of the road ahead (see Clause 5.4.3). Where the luminaire outreach is mounted at an angle to the carriageway, care should be taken to avoid presenting misleading visual information to the motorist (see Clause 7.2.6).

7.3 ENVIRONMENTAL CONSIDERATIONS

7.3.1 General

The effects a road lighting system may have upon the environment should be minimized at the design stage. This is increasingly important as the general public become aware and voice concerns and government policies are implemented to counteract adverse environmental impact. Particularly important is the minimization of energy use and consequent greenhouse gas emissions associated with road and public space lighting. Often minimizing environmental impact will lead to reduced direct costs of the lighting system.

7.3.2 Energy usage

Energy usage through the life cycle of the lighting system should be minimized by the following:

(a) Selection of the lowest lighting sub-category appropriate for the particular road type and operating characteristics (see AS/NZS 1158.1, Table 2.1). Provision of adequate but not excessive illuminances and luminances to comply with the requirements of that specific lighting sub-category. The lighting levels set for each sub-category are adequate and not excessive for the particular application and should not be arbitrarily reduced. The efficient use of other road safety devices such as perimeter line marking (visual and audible) and retroreflective, wherever possible, to minimize the need for higher lighting levels or additional lighting.

(b) Limiting the equipment used, such as luminaires, columns, cabling. For example, all other considerations being equal, a central median mounted system needs less initial equipment that an opposite arrangement. Cut-off luminaires need to be placed closer together than semi cut-off ones.

(c) The use of energy-efficient lamps and equipment will minimize electricity use.

(d) The use of a maintenance factor that is as high as possible for the road pollution category (see Section 14). The luminaire used should have an IP rating of 6X and the lamp as good as possible lumen maintenance in order to maximize the length of the maintenance cycle (see AS/NZS 1158.1, Clause 2.10, Section 14 and Appendix E).

7.3.3 Spill light

Light emitted beyond the bounds of the carriageway and upward is, in general, wasted light and energy and the following can have adverse environmental impacts:

(a) Upward light is scattered in the atmosphere and results in artificial sky glow, which inhibits the clear view of the heavens for both astronomers and casual viewers. Upward light from luminaires is controlled by a specified maximum value of Upward Waste Light Ratio (UWLR) (see AS/NZS 1158.1, Clause 2.6). Many current semi cut-off luminaires have UWLR values of close to 1%. However some upward light may be beneficial on roads with an over-arching tree canopy (see Clause 8.8). The use of upcast of the luminaires, beyond the 5 degrees normally used for aesthetic purposes, should not be used to spread light across a wide road, instead adequate toe-in within the luminaire should be utilized. In particularly sensitive situations, such as in the vicinity of astronomical observatories and airports, cut-off luminaires should be used.

(b) Sideways spill light into properties and the direct view of luminaires may become obtrusive to residents (see AS 4282). Category V lighting is generally exempt from the provisions of AS 4282 due to the high levels of lighting necessary and because the lighting provides the community at large with an effective night crash counter measure. In sensitive situations, various measures may alleviate spill light problems, e.g. placement of lighting points, use of shields in the house-side of the luminaire visor or the use of cut-off luminaires.

7.3.4 Glare

Besides the possibility of a direct view of luminaires by residents, there is the view of the luminaires by both motorists and pedestrians using the roadway. The disability aspect of glare is adequately controlled by the specification of a maximum permissible value of threshold increment (*TI*) (see AS/NZS 1158.1.1, Table 2.2 and AS/NZS 1158.2, Clause 2.1.5). However, where semi cut-off luminaires are specified by the installer to achieve the greatest spacing possible, the value of TI will be close to the permissible limit. Thus there is a risk that these luminaires may appear overly bright and somewhat discomforting over a lengthy lighting system.

7.3.5 Colour of light

With the advent of metal halide lamps emitting white light, of high efficacy and reasonable lumen maintenance and lamp life makes these lamps an attractive proposition. They may be used in city and suburban centres where the associated high colour rendering values will enhance the perceived colourfulness and brightness of these environments. However, high pressure sodium lamps, although emitting yellow light of poorer colour rendition, are preferred for the lighting of the generality of traffic routes since these lamps offer the higher reliability and efficacy and hence energy efficiency (see AS/NZS 1158.1, Clauses 2.7 and 2.8). High pressure mercury lamps shall not be used in Category V lighting systems.

7.4 TREE-LINED TRAFFIC ROUTES

Where trees are planted at the roadside or in the road shoulders and partially overhang the carriageway, the light output from conventionally placed luminaires may be obstructed. Where the trees are large, of spreading habit and very substantially or completely overhang the carriageway, conventional placement of luminaires is generally impracticable. Guidance for the lighting designer is given in Clause 8.8.

7.5 WEATHER CONDITIONS

7.5.1 Effects on visibility

7.5.1.1 *Wet conditions*

As a paved surface passes from the dry state through stages of being damp, wet and finally flooded, its reflecting characteristics change. When merely damp, the effectiveness of the lighting installation may be reduced very little, if at all. Thereafter, reflection changes from diffuse to specular, and visibility deteriorates. Bright patches contract into bright streaks leaving areas of comparative darkness between. The distorted specular image has a brightness and width comparable with that of the light source.

When wet, painted line markings, including those with retroreflecting beads, tend to lose their contrast with the road surface. Lane marking studs continue to be visible while retroreflecting signs and markers lose none of their effectiveness.

Road verges, particularly if dark in colour and rough in texture, appear darker, as do objects on them and contrast is thus diminished.

Visibility is further impaired in wet conditions because of the presence of water droplets and road dirt in the atmosphere and on vehicle windscreens, which deflect, absorb and reflect light.

7.5.1.2 *Foggy conditions*

The conditions described in Clause 7.5.1.1 will, in general, also apply when fog is present. Additionally, visibility is further affected as a consequence of light from a vehicle's headlights being reflected back from the densely packed water droplets in the direction of the driver's eyes. The scattering of light from the water droplets produces a luminous glow that inhibits visibility of distant objects.

7.5.2 Means of improving visibility

The use of reflective material such as white paint or retroreflective markers is of great value at all times and may be essential for safety in wet or foggy weather (see Clause 7.9).

The revealing of the road ahead, especially on bends and curves, is greatly assisted in bad weather by logical placement of luminaires as seen in perspective. Misleading placement may cause crashes (see Figure F14, Appendix F).

The most critical light technical parameter to be considered in designing for wet carriageway conditions is the overall luminance uniformity (U_O). This uniformity can be enhanced by one or more of the following:

(a) Reducing the spacings of the luminaires.

(b) Increasing the luminaire mounting height.

(c) Selecting a luminaire with a greater toe-in.

(d) Changing the overhang.

In fog-prone areas, the use of high pressure sodium vapour luminaires is recommended due to their ability to more efficiently penetrate the fog, due to lower atmospheric scattering compared to other current light sources.

Lighting above the minimum requirements of AS/NZS 1158.1.1 is especially advantageous in wet or foggy weather due to improved visibility and route guidance afforded by the higher illumination of objects.

7.6 REFLECTING PROPERTIES OF ROAD SURFACES

Because a primary objective of roadway lighting is to produce bright road surfaces, the reflecting characteristics of that surface are vital factors affecting both the luminaire design and planning of the luminaire layout. The light technical parameters specified in AS/NZS 1158.1.1 are based on the reflecting characteristics of the following standard road surfaces:

(a) *In Australia* The light parameters are based on the reflecting characteristics of the CIE R3 road surface (see Table 3.1), which is an asphaltic concrete surface that is dry in a moderately worn condition. It has been shown, based on an analysis of the limited data available on the reflecting properties of Australian road surfaces, that the choice of the CIE R3 road surface is appropriate.

    The CIE R3 road surface will also be applicable for surface-treated pavements that have reflecting characteristics that vary much more widely according to the state of wear, but have average characteristics that are, in general, not dissimilar to those of the dry asphaltic concrete surface.

    Concrete surfaces have reflecting characteristics little different from those of bituminous pavements, but can exhibit high luminance values because of their better diffuse reflectance. Variation in texture and colour may improve visual conditions, but should not influence the lighting design.

(b) *In New Zealand* NZR2 and NZN4 road surfaces apply for the purposes of calculating the light technical parameters. Compliance is to be achieved in calculations involving both of these surfaces. The NZR2 surface is typical of a new chip seal (diffuse) surface, and NZN4 of a polished asphaltic (glossy) surface. These represent the two extremes in reflection properties of New Zealand roads.

7.7 ROAD LAYOUT

In designing a road lighting installation, instances will occur where, for aesthetic or practical reasons, departures from the recommended geometry will be necessary. Also, locations may be encountered where visibility problems exist by day as well as by night, due primarily, or even in some cases entirely, to the road layout features.

In such cases special treatment will be required. As road lighting is an integral part of road design, the cooperation of road authorities and electricity supply authorities may be needed in arriving at a satisfactory solution. On occasions, potentially troublesome areas are not evident from roadway plans. The lighting designer should therefore undertake an inspection of the site at an early stage to establish the topography of the area and to locate existing features such as drains, trees, bridges, overhead conductors or other obstructions that may not be shown on the base drawings.

7.8 ROADWAY FEATURES

Visibility of roadway features (e.g. kerbs, islands) depends largely on brightness contrasts produced by diffuse reflections from the relevant surfaces (i.e. upon their ‘lightness’ and ‘darkness’). It follows that the effectiveness of a lighting system will be greatly enhanced if contrasting colours or textures can be introduced into the roadway features.

These considerations are particularly important at channelizations and where medians with mountable kerbs are used.

7.9 SURROUNDING BACKGROUNDS TO ROAD

A specific requirement for the lighting of traffic routes is the provision of illumination on the immediate verges or footpaths to the carriageway (light technical parameter E_S). It follows therefore that a significant proportion of the luminous flux from the luminaires will be directed to that area and beyond. It is advantageous if this light falls on light coloured surfaces, particularly vertical surfaces facing the carriageway, because the surroundings as well as the carriageway surface itself, will appear relatively bright to road users. This will add to the effectiveness of the road lighting in further raising the general light adaptation level of the road users, so improving visibility and reducing glare.

It is not realistic to expect the surrounds to roads, such as building facades, walls and fences, to be always light in colour. However, when the opportunity arises, as in planning new, or refurbishing, land development and roads, it may be feasible to incorporate this principle in the design requirements. One example would be to deliberately use light-coloured surfaces on any noise barriers adjacent to the roadway.

A corollary is that the lighting installation itself should be as effective as possible where the surrounds to the road are dark. This will arise where there is extensive abutting foliage or where building facades are dark coloured or are distant from the roadway. In these cases consideration should be given to the provision of a somewhat higher level of road luminance and more restrictive glare control than is warranted by the lighting category otherwise applicable to the particular road type and operating characteristics.

7.10 VISIBILITY OF ROAD SIGNS

A road lighting installation should not be adjusted to light road signs but every effort should be made to avoid the installation obscuring or otherwise distracting from their visibility, including such influences as background glare.

Attention should also be given to the possibility of specular reflections from road lighting luminaires interfering with the legibility of signs. Usually there is some latitude for signs to be adjusted or moved within limits to fit in with the road lighting layout. Where this is not possible because of structural or other considerations, such as a critical location for a large sign, the position of the luminaire may need to be reviewed.

To ensure adequate visibility at night, the use of independently illuminated signs should be considered. However, care should be taken that these are not a source of glare to the motorist. Where the road lighting employs sources of predominantly monochromatic light (e.g. low pressure sodium vapour lamps), it is generally necessary to illuminate the signs independently to restore a reasonable colour appearance.

7.11 AESTHETICS

At all times consideration should be given to the aesthetic appearance of the lighting equipment used. While aesthetic evaluations rely largely on subjective assessment and often on personal preference, it is desirable to consider this aspect, particularly in sensitive areas, e.g. in the vicinity of cultural and civic centres.

The ability of the lighting layout to be in scale and to harmonize with its surroundings requires careful appraisal by appropriately skilled people.

SECTION 8 DESIGN RECOMMENDATIONS

8.1 INSTALLATION GEOMETRY

8.1.1 Required data

The geometric parameters of the installation should be determined in accordance with Clauses 8.1.2 to 8.1.4. These parameters are defined in AS/NZS 1158.0 and are illustrated in Figure 8.1 of this Standard.

8.1.2 Carriageway lighting design width (W_K)

The installation should be designed to adequately light the whole of the used portion of the road, whether or not it is sealed across the full width. In some cases there may be difficulty in deciding just what width of road should be used for design purposes. It is then necessary to exercise judgement in determining how much of the road is normally used by vehicles, either moving or stationary (taking into account breakdown lanes and parking lanes), and therefore needs to be lit, and to take the boundaries of this portion of the road as the carriageway edges.

The point at which pedestrians become vulnerable is a factor that may need to be taken into account. For example, a road might consist of a narrow, sealed pavement with very wide shoulders in which a row of trees is planted with spaces between the trees, that can be used for manoeuvring and parking vehicles. In this case, the installation will need to be designed to light the whole width between the tree trunks, and the line of tree trunks would then be taken as the carriageway edge.

8.1.3 Lighting arrangement (AAR) and mounting height (H)

The required lighting arrangement and mounting height will depend on the road cross-section and should be commensurate with the carriageway lighting design width. The following guidelines are given to establish a mounting height to serve as a starting point for design:

(a) *Single carriageway*:

ARR 1,2 (single side) for W_K around H

ARR 3 (staggered) for W_K around 1.5 H (1.25 H for aeroscreen luminaries)

ARR 4 (opposite) for W_K around 2 H

(b) *Dual carriageway*:

ARR 5 (opposite), 5S (staggered) for W_K around 1.25 H

ARR 6 (central) for W_K around 1.25 H

ARR 7 (twin staggered) for W_K around 1.75 H

ARR 8 (twin opposite) for W_K around 2.5 H

Consideration should be given to obstructions in the median that might preclude any light contribution from luminaires on the opposite carriageway (e.g. dense plantations of tall shrubs and trees as landscaping (see Clause 8.8), headlight shield, noise barrier and the effect of the width of the median (see Clause 8.4). However, the effect of median barriers may be ignored (see Clauses 8.3 and 8.4).

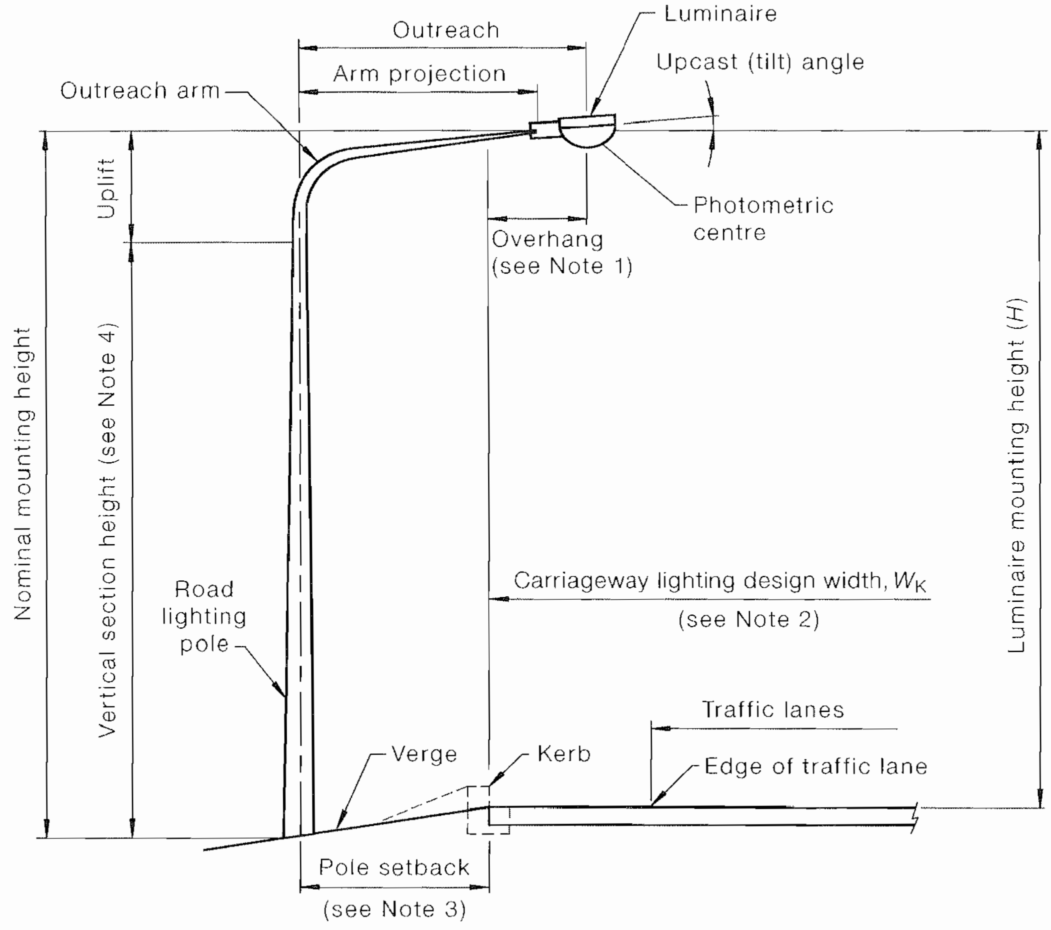
The mounting height should generally be not less than 9 m for Category V4 and V5 luminaires and not less than 10.5 m for Category V1, V2 and V3 luminaires unless special conditions exist, e.g. in the vicinity of airport runways or for bridge parapet lighting.

Where dedicated lighting poles are used, it is recommended that the luminaire mounting height (*H*) correspond to one of the preferred nominal mounting heights, e.g. 9 m, 10.5 m, 12 m, 13.5 m or 15 m (see AS 1798). Where existing electricity distribution poles are used, mounting heights other than the preferred values referred to above may need to be adopted.

NOTE: AS 1798 is an Australian only Standard.

In any one installation the mounting height should, as far as possible, be kept constant to preserve continuity of the line of luminaires.

Subject to attainment of the required values of luminance or illuminance, as applicable, the use of greater luminaire mounting heights will lead to improved uniformity of these parameters, fewer lighting poles and lower operating costs. However, account should be taken of economics (e.g. from the use of existing structures), aesthetics and maintenance (e.g. ability to access the luminaires). It should be noted that the adoption of greater mounting heights will necessitate the use of luminaires with a higher light output and may unnecessarily increase the light spilled into properties abutting the roadway.



NOTES:

1 Overhangs of between 0 and *H*/4 will generally achieve the best lighting designs.

2 W_K is the width of that part of the carriageway that is used for calculation or assessment of road lighting (see Clause 8.1.2).

3 Pole setback is the horizontal distance between the edge of the carriageway and the centre-line of the lighting pole, measured normal to the direction of traffic. Shoulders and breakdown lanes should be taken as part of the carriageway.

4 Vertical section height is only applicable where a detachable outreach arm is used.

FIGURE 8.1 ROAD LIGHTING DESIGN PARAMETERS

8.1.4 Overhang

It is recommended that the selected luminaire overhang lie between zero (0) and one quarter of the luminaire mounting height ($H/4$). The larger overhang will increase average carriageway luminance but may adversely affect uniformity. However, a negative overhang may be used when necessary to attain the required values of overall luminance uniformity (U_0) or where long outreach arms are impracticable or undesirable.

8.2 LAMP WATTAGE

Table 8.1 provides indicative mounting heights for luminaires that utilize high pressure sodium vapour discharge lamps. These mounting heights have been found, from practical experience, to provide an efficient utilization of the available luminous flux output.

TABLE 8.1

INDICATIVE MOUNTING HEIGHTS AND LIGHTING CATEGORY FOR LUMINAIRES WITH HIGH PRESSURE SODIUM AND METAL HALIDE LAMPS

Lamp rating	Mounting height	Category
W	H	
100	9.0	V5 and V4
150	10.5	V5, V4 and V3
250	10.5 – 12.0	V3 and V2
400	>12.0	V2 and above

8.3 MEDIAN BARRIERS

Where Type F concrete or steel median barriers are used as part of the road construction, the inclusion of centrally mounted lighting columns on them can provide a cost effective lighting solution. In these applications the location of lighting columns may be determined by the modular arrangement of the barrier and structural considerations may also apply to the minimum distance between a column and the nose of a barrier. Design coordination will be required early in the road and lighting scheme design for power cable location, looping and terminations either within a concrete barrier, within the pole base or within trenching under concrete or steel barriers.

8.4 MEDIAN

The carriageways of divided roads should be treated as two separate roads, where any of the following occur:

(a) The width of the median is greater than the width of one carriageway.

(b) Tall and dense shrubbery exists or future plantings are proposed.

(c) Except for the provisions of Clause 8.3, there is or will be a median barrier higher than 1 m.

8.5 CURVES AND BENDS

The general approach to the design of lighting on curves is to locate luminaires on one side of the road at closer spacings than those that apply for straight sections of the same width.

In the past, it was common practice for luminaires to be located on the outside of a curve. However, a major Australian crash study (see Ref. 9 in Paragraph A2) involving collisions with utility poles found the probability of poles being hit on the outside of a curve was higher than for those on the inside of the curve. For this reason, where luminaires are to be located on the outside of a curve, particular attention should be given to the type of poles selected and their location (e.g. setback), to minimize the hazard to motorists.

To maintain a consistent visual appearance for motorists, the lighting arrangement used on the adjacent straight section should, in general, be continued throughout the curve.

On wide roads, it may be necessary to install luminaires on both sides of the curve. An opposite arrangement is to be preferred for this purpose.

8.6 ROUNDABOUTS

8.6.1 General

A roundabout should be clearly recognizable well in advance on approach. The form of the central island and the channelization on the entrance and exit roads should be clearly distinguished, so that the intersection is not confused with a T-junction or crossroad. In addition, traffic on the approach roads and in the roundabout should be clearly distinguished so as to elicit the correct traffic behaviour by motorists.

The roundabout will normally need lighting additional to the road lighting on the approach roads. The lighting on the approach roads should be continued up to the roundabout. The additional lighting needs to be placed so it is not a potential traffic hazard.

On the immediate approaches to and on roundabouts, there are four basic types of manoeuvres. These are diverging, merging, crossing and weaving. At places where manoeuvres are made, conflicts occur and there is potential for a crash. Adding to these conflict points are hazards due to additional roadside furniture such as road lighting poles.

From research, the conflict areas surrounding a roundabout can be identified (see Figure 8.2) as follows:

(a) Splitter islands.

(b) Central island directly opposite an entry carriageway.

(c) Left-hand verge of roundabout perimeter (especially downstream of an entry point).

(d) Left-hand verge on exit carriageway.

(e) Left-hand verge on entry carriageway, adjacent to trailing nose of splitter island.

When designing the lighting for roundabouts, account should be taken of the conflict areas identified above (see also Figure 8.2). It will be seen that one of the safest locations for road lighting poles is on the central island of the roundabout. However, roundabouts can be lit from the outside provided the poles are—

(i) located outside the conflict areas; and

(ii) set back at least 3 m from the kerb.

Where it is unavoidable that poles be located within conflict areas, the recommendations of Clause 8.6.7 should be observed.

Recommendations for the location of road lighting poles on roundabouts are given in Clauses 8.6.2 to 8.6.6, and are illustrated in Figures F14 and F15 of Appendix F. The design procedure for roundabouts is illuminance-based and the minimum design area is illustrated in Figure 3.10 of AS/NZS 1158.1.1. The additional luminaires will often be mounted on poles higher than those used to light the approach roads. The additional luminaires may be floodlights rather than road lighting luminaires. However, care should be exercised to ensure that glare from the floodlights is restricted, as is required for the road lighting luminaires.

8.6.2 Road lighting poles located on central island of diameter less than 6m

Where the central island of the roundabout is less than 6 m in diameter, the installation of road lighting poles within the island should generally be avoided. However, when it is necessary to install a pole within the central island, it is recommended the pole used be of the energy absorbing type.

8.6.3 Road lighting poles located on central island of diameter between 6m and 40m

Where the central island is relatively small it may be advantageous to light the design area from a single conventional/high mast pole situated at or near the middle of the central island (see Figure F14).

8.6.4 Road lighting poles located on central island of diameter between 40m and 60m

Where the central island is of medium size, a cost benefit analysis should be made to determine the appropriate treatment, either in terms of Clause 8.6.3 or Clause 8.6.5.

8.6.5 Road lighting poles located on central island of diameter greater than 60m

Where the central island is large, it may be more appropriate to light the design area from conventional poles positioned around the perimeter of the central island (see Figure F15).

8.6.6 Road lighting poles located outside the roundabout

The poles should be located as recommended in Clause 8.6.1. It is advantageous to locate the poles towards the boundary line of the road reserve and approximately midway between the approach roads. If the roundabout is a four-way intersection, four positions can be used for roundabouts of larger diameter and two, diagonally placed, for the smaller roundabouts. Lighting from the outside of the roundabout will facilitate the illumination of the sides of vehicles in the roundabout.

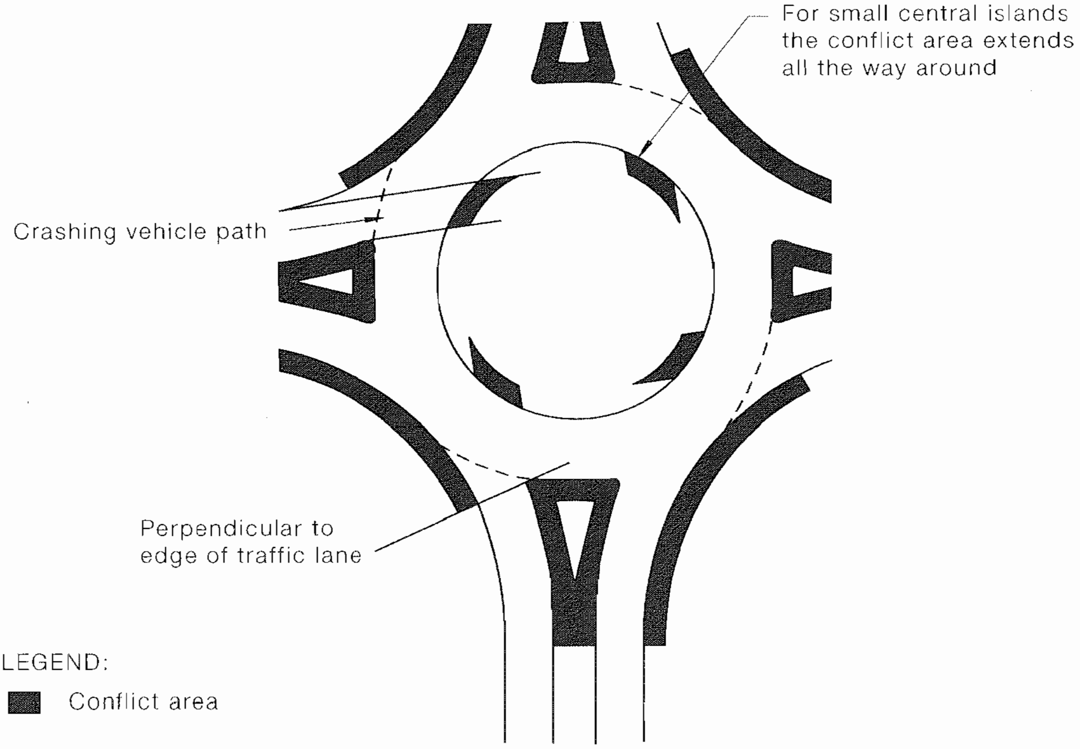

For small central islands the conflict area extends all the way around
Crashing vehicle path
Perpendicular to edge of traffic lane
LEGEND:
▩ Conflict area

FIGURE 8.2 CONFLICT AREAS IN ROUNDABOUTS

8.6.7 Road lighting poles located at conflict areas

Where road lighting poles are to be positioned in any of the conflict areas identified in Figure 8.2, it is recommended that the poles used be of the frangible type. However, it should be noted that these poles are likely to be hit by vehicles and there will inevitably need to be ongoing replacement/maintenance.

8.7 CRESTS AND HUMPS

8.7.1 Visibility problems

A crest or hump in the roadway may create the following problems of visibility:

(a) Absence of background, except sky or other distant unlit background beyond the crest.

(b) Partial or complete concealment of objects beyond the crest.

(c) A confusing pattern of luminaires mounted beyond the crest which, in the absence of backgrounds on the carriageway and verges, can conceal objects, be confused with the lights of vehicles and give a misleading indication of the road ahead.

(d) Glare from luminaires just beyond the crest, especially over a crest of short radius.

(e) Sudden glare from dipped headlights as they appear over the crest.

8.7.2 General recommendations

In order to minimize the visibility problems outlined in Clause 8.7.1, the general illumination on or near the crest should be substantially increased as required for compliance with Section 3 of AS/NZS 1158.1.1.

Particular attention should be given to indicating the course of the road beyond the crest, especially of bends, by the appropriate location of luminaires and increased luminaire mounting height, where necessary, for visual guidance beyond the crest.

Luminaires should be correctly aligned with respect to the road surface so the luminaire is parallel with the grade of the road at its centre-line.

8.7.3 Glare at crests from luminaires

Luminaires may cause glare when mounted at or near a crest if the particular angles of view are such that the motorist passes in and out of the main beam of the luminaire as the vehicle negotiates the crest.

This will manifest itself as an extended flash of quite severe glare from one or more luminaires as the motorist approaches or passes over the crest. When this effect is experienced, it can sometimes be remedied by slightly adjusting the alignment of the offending luminaire(s) relative to the road surface. Care should be taken to ensure the effect is not thereby aggravated for motorists approaching the crest from the other direction.

8.8 TREE-LINED TRAFFIC ROUTES

8.8.1 Influence on light technical parameters

Trees can cast significant shadows on the roadway and verges and the calculated values of the light technical parameters will be compromised. The road lighting design procedure does not take into account the presence of trees unless specific allowance is made for their presence. Unless specific allowance is made in the design and installation of the lighting scheme, the organization paying for the lighting will not obtain the expected compliance lighting performance.

8.8.2 Tree management policies

The lighting service provider and the organisation to which the lighting is provided will, in general, not have an agreed policy for vegetation management around lighting schemes. The latter may have a road landscaping policy that contains little on the integration of trees, pruning and lighting whilst the former may only prune trees and shrubs to maintain a specific clearance between foliage and cables for the overhead reticulation of electricity and telecommunications assets.

It is therefore to the benefit of both the lighting service provider and the organisation to which the service is provided to have a common policy on integrated road landscaping and lighting.

8.8.3 A model policy on integrated road landscaping and lighting

8.8.3.1 *Principles of the policy*

The policy takes into account the following aspects of the landscaping and of the lighting scheme:

(a) Established and new landscaping.

(b) The arrangement type of lighting scheme and the height, location and type of luminaires.

(c) Plant species taking into account required canopy height and spread.

(d) Canopy pruning (not merely pruning for conductor and cable clearance).

(e) Plant location with respect to luminaires.

8.8.3.2 *Existing trees and plantings*

The policy for existing road landscaping depends on the lighting arrangement to be used.

(a) *Opposite or staggered lighting arrangement* Where there are tall trees with a wide canopy, mount the luminaires below the canopy and maintain the lower canopy to approximately 1 m above luminaires to avoid shadowing on the carriageway and verges, as in Figure 8.3. In order to minimize or obviate pruning where the trees are a sensitive issue and major pruning is not an option, a lower mounting height and greater overhang than normal may be necessary to effectively achieve the specified lighting performance. This may necessitate closer spacing of the luminaires.

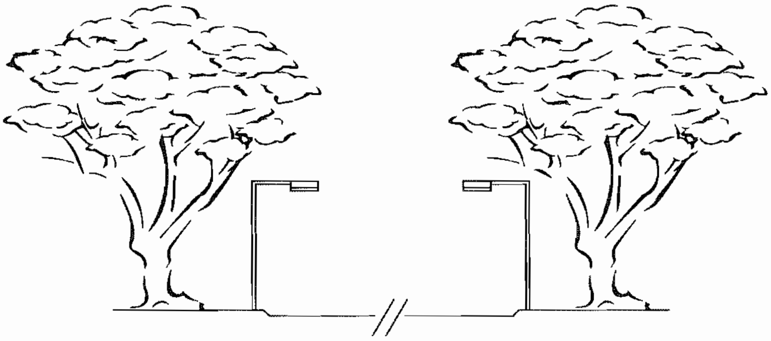


FIGURE 8.3 LIGHTING WITH TALL TREES AND WIDE CANOPY

If along one or both sides of the road there are low trees or shrubs, the luminaires should be mounted above the maintained nominal canopy height (C) of these plantings such that $H - C \approx 2$ m in order to allow light penetration downwards to any footpath, as shown in Figure 8.4.

Where there is a median and any central plantings are dense and exceed 1 m in height—sufficient height for a headlight screen—then these plantings will impede the light from one row of luminaires reaching part of the opposite carriageway. In such cases, each carriageway should be considered as a separate road for the purpose of the lighting installation design.

(b) *Central lighting arrangement* Where there are tall trees in the median with a wide canopy, as in the Figure 8.3, the same mounting techniques as set out in the preceding paragraph should be used. Where, as is more likely, the trees or shrubs have narrow canopy spread and a low height, the luminaires should be mounted at approximately 1 m above the maintained nominal canopy height, preferably with greater overhang than normally warranted, to prevent shadows on the carriageway.

If there is unavoidable excessive height of the trees, which impedes the light from one row of luminaires reaching part of the opposite carriageway, then in such cases each carriageway should be considered as a separate road for the purpose of the lighting installation design.

(c) *Single-sided lighting arrangement* Where there are tall trees with a wide canopy, luminaire mounting techniques should be used as set out for the opposite lighting arrangement.

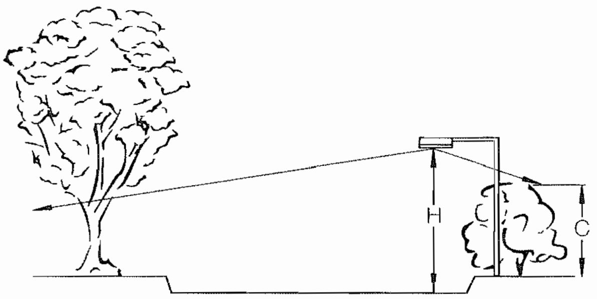


FIGURE 8.4 LIGHTING WITH LOW CANOPIES

If there are low trees or shrubs alongside the road, the luminaires should be mounted above the nominal canopy height C such that H – C ≈ 2 m to allow light penetration downwards to the verge and any footpath, as shown in Figure 8.4. If there is high canopy on one side and low on the other then the lighting should be placed on that side of the road if possible. The canopy of the tall trees on the opposite road side should not have foliage below ~4 m, to allow light penetration downwards onto and along the opposite verge and any footpath.

(d) *Other general considerations*

(i) When trees are planted on the footpath side of the kerb line, the carriageway lighting design width should be as determined in the normal way in accordance with Clause 8.1.2. When the trees are planted on the road shoulder, the carriageway lighting design width will usually be taken to the line of tree trunks.

This may not apply, however, when it becomes necessary to exercise judgement in determining how much of the road is normally used by vehicles, either moving or stationary, and therefore needs to be lit. One case would be where the road shoulders to the adjacent tree trunk line are not so formed as to be trafficable. Another case would be where there are gaps in the tree lines and the road shoulders are useable right to the kerb line. In this latter case, it is recommended that the carriageway lighting design width of the installation be appropriately increased where the length of the gap in the tree line exceeds 100 m.

The point at which pedestrians become vulnerable is a factor that may also have to be taken into account (see Clause 8.1).

(ii) Where the tree trunks are massive and/or close together there may be a need to provide separate lighting, because of excessive shadowing, for any footpath or service road (see AS/NZS 1158.3.1 Table 2.2 e).

(iii) Sufficient clearance needs to be maintained between a lighting pole or column and adjacent tree or shrub for maintenance work.

(iv) Foliage has poor reflectance, especially to sodium lighting, therefore a higher wattage of lamp and/or white light will be beneficial. This is especially so if the canopy is over arching. In this case, more upward light will be beneficial in mitigating a gloomy tunnel appearance. Cut-off luminaries should not be used in such situations.

8.8.3.3 *New landscaping*

Where new landscaping is to be undertaken where there is an existing lighting system, the landscape should be integrated with the lighting system using the principles as set out in Clause 8.8.3.1

Where both landscaping and a lighting system are to be installed on a road, the two should be integrated using the principles set out in Clause 8.8.3.1.

8.9 SHORT BRIDGES, UNDERPASSES AND SHORT TUNNELS

8.9.1 Short bridges

For short bridges, of length generally less than 150 m, the carriageway and surrounds should be lit to not less than the requirements that apply for the adjoining section of roadway. For very short bridges, of length generally less than 40 m, road lighting equipment should, preferably, not be placed on the bridge structure. In other cases, it may be necessary to attach luminaire support structures to the bridge in order to satisfy the lighting requirements.

From an aesthetic viewpoint, an opposite arrangement is generally preferred. However, the use of a single-sided arrangement is preferable on narrow carriageways.

8.9.2 Underpasses and underbridge carriageways

Where the carriageway is covered forming an underpass, daytime lighting may be required when:

(a) The length of the underpass is equal to or greater than ten times the minimum roof height.

(b) Specific situation analysis detailed in AS/NZS 1158.5:2007 determines the underpass to be Cat TU3 or TU4.

Where the road is determined to meet Cat TU5, the requirements of AS/NZS 1158.5:2007 Clause 4.3.4 shall apply.

For underpass of Cat TU5 of less than 30 m length, luminaires need not be installed within the underpass if it can be demonstrated that the required lighting performance can be attained using luminaires located on the outside. To achieve this condition, it may be necessary to reduce the mounting height of the luminaires immediately outside the underpass and to change other installation geometry. Where this action is contemplated, consideration should be given to possible adverse effects for users of any transport system above the underpass.

8.10 ORIENTATION OF LUMINAIRES

Road lighting luminaires installed on traffic routes should be correctly orientated to ensure that, for the particular design parameters used, the proper distribution of road luminance/illuminance, together with the minimum of glare to motorists, will be achieved. The luminaire alignment should be parallel to the grade of the road at its centre-line.

8.11 TERMINATION OF ROAD LIGHTING

When a lighting installation is terminated and drivers rely on their headlights, cognizance should be taken of the need for the eye to adapt to the new conditions. In this respect it is recommended the lighting installation should not be terminated at a hazardous location (e.g. approach to a narrow bridge or bend), or at an area where complex traffic movements take place. Where possible, continuity of delineation of the route ahead should be provided by such measures as edge-lining and use of reflective pavement markings.

SECTION 9 DESIGN METHODS

9.1 GENERAL

Category V lighting shall be designed using one of the design methods specified in Table 3.1 of AS/NZS 1158.1.1 for the appropriate road element, e.g. straight section, curve and intersection. The lighting scheme design for a straight section will be luminance based, whereas for some other road elements, such as intersections, it will be illuminance based. For these road elements this will involve computer calculations. For some road elements, such as isolated intersections, a design rule shall be used instead. In the case of curves with a radius of curvature equal to or greater than 100 m, the curve spacing chart derived from complex computer calculation shall be used.

9.2 COMPUTER DESIGN

9.2.1 General

Computers with the appropriate software will generally be used in the design of lighting for straight and curved sections of roads, for intersections, and other designated locations.

9.2.2 Straight road sections

The design area for a straight road section will be the carriageway width (W_K) and one span length (S) of the lighting arrangement (ARR) chosen. W_K will be used regardless of whether the road is single or double carriageway. In the case of a double carriageway road the median width will also be an input and the calculation procedure will recognise the second carriageway. The spans will then be duplicated to fill the required road length. The maximum complying lighting scheme value of S may not be practicable because of constraints in pole position but any modification of S must be such that the maximum is not exceeded.

The software for the design of lighting schemes for straight sections of roads must utilize the calculation program SAASTAN in order to fulfil the road lighting scheme design compliance requirement of AS/NZS 1158.1.1. SAASTAN, as set out in AS/NZS 1158.2, will only handle the input of one set of values for the design parameters at a time. A number of commercial software packages that will handle the input of multiple values of design parameters are available. There is a listing of the relevant businesses in Appendix C of AS/NZS 1158.2.

It should be noted that computers with the appropriate software do not in fact design road lighting installations; they calculate the light technical parameters for the input designs to determine compliance with the relevant values specified in Section 2 of AS/NZS 1158.1.1.

To minimize the number of calculation runs necessary to arrive at a final design for a straight section, a number of values for luminaire spacing, S, generally can be inputted and the computer output will nominate those spacings that comply or fail. For a given W_K there generally will only be a limited choice of luminaire mounting height, H, and overhang, O. This is because of the standard range of poles and bracket arms used by the lighting service provider and of the inherent relationship between ARR, W_K, H and S as set out in Clause 8.1.3 of this Standard.

9.2.3 Intersections, curves(R <100 m) and other designated locations

9.2.3.1 *General*

The design areas for these road elements are listed below.

9.2.3.2 *Intersections (including roundabouts)*

The principles for determining the design area of a complex intersection are shown in AS/NZS 1158.1.1, Figure 3.9 whilst those for simple intersections employ the 10 m rule, as shown in Figure 3.8 and 3.10. Indicative lighting schemes for intersections, are shown in Appendix F. However all lighting schemes must be verified for compliance with the required light technical values by computer calculation.

9.2.3.3 *Curves (R <110 m)*

The principles for determining the design area of curves of low radius is shown in AS/NZS 1158.1.1, Figure 3.5. For curves of very low radius (R <30m—virtually right angle bends) the 10 m rule is employed as shown in Figure 3.6.

9.2.3.4 *Other designated locations*

Other designated locations are changes in carriageway width (AS/NZS 1158.1.1, Figure 3.2), channelized converging/diverging traffic (AS/NZS 1158.1.1, Figure 3.4) and pedestrian refuges (AS/NZS 1158.1.1, Figures 3.11 and 3.12).

There is no specified computer calculation program as SAA STANSHELL for illuminance based designs. General area lighting calculation programs may be used but spacing of the test points shall be as set out in AS/NZS 1158.1.2. For small design areas, such as those associated with changes in design width, an isolux diagram may be sufficient to demonstrate compliance. These diagrams may be readily produced for the luminaire by the software. Care should be taken in ensuring the scale of the diagram is that of the design area and that the diagram is correctly orientated in use.

9.2.4 Curves (R ≥100 m)

The curve spacing chart of Figure 3.7 in AS/NZS 1158.1.1 shall be as the basis for the design of lighting on curved sections of roadway. The design procedure for the use of the curve spacing chart is set out in detail in Clause 3.3.4 of AS/NZS 1158.1.1. However, the following points need to be emphasised:

(a) The lighting on the curve will involve closing up the spacing of luminaires determined for the preceding straight section. If there is no lit preceding section then the spacing applicable to a straight section of the same carriageway width as that of the curve shall be used.

(b) The lighting design will require a decision as to which side of the roadway the majority of the lighting will be placed (except for central lighting arrangements). Simple road safety considerations may lead to the choice of the inside of the curve but that will necessitate more luminaire than the outside of the curve, which would be the conventional lighting choice.

(c) If a central arrangement is used on the preceding straight then that arrangement, closed up, will be used in the lighting of the curve.

(d) In applying the design method the roadway width shall be used, i.e. the transverse distance of outer kerb to the far outer kerb line. For single carriageways this will be W_K and for double carriageway roads it will be $2 \times W_K$ plus the median width.

SECTION 10 DESIGN OF INSTALLATION

10.1 PROCEDURES USED IN LIGHTING DESIGN

The following is a step-by-step guide to designing lighting for a section of road, including intersections that may be used irrespective of the method of design adopted:

(a) Assemble appropriate scale base plans showing the road layout including features such as carriageways, footpaths, verges, intersections and islands, signalization, control lines, chainages, relevant underground ducting and services, along with all other items, as listed in Clause 10.3.2, that may influence the lighting layout.

(b) Select a luminaire and lamp combination from those most suitable for the application and obtain up-to-date design aids such as isolux diagrams, spacing tables, performance tables and I-tables (required for computer-based techniques). Ensure the I-table is for the individual luminaire/lamp combination desired and not just a lamp lumen adjustment of a universal type I-table.

(c) Determine a trial arrangement for evaluation. This will involve the selection of a mounting height suitable for the various limiting factors such as road width or overhead power line clearances (where relevant), or environmental/aesthetic considerations. It will also be necessary to determine the outreach arm projection and the location of the luminaire relative to the edge of the carriageway, i.e. the overhang.

(d) Determine a trial spacing either directly from the luminaire spacing or performance tables, or by judgement.

(e) Lay out the luminaire positions at the key locations along the route as a trial, taking care to ensure critical areas are adequately illuminated. This may involve a full intersection lighting design using one of the methods discussed in Section 9.

(f) Lay out the luminaire positions along the road using the trial spacings as a guide. Adjust this, where necessary, to fit economically between the previously arranged intersection lighting, and to satisfy other limitations on luminaire positioning, for example, due to median openings, driveways, overhead clearance problems. Adjustments may also be necessary to ensure locations such as pedestrian areas and bus/tram stops are well lit.

(g) Check the achievement of the desired values of the light technical parameters by applying one of the design methods to the resultant lighting layout. This may be done for a typical span of route lighting or for any span where the layout changes significantly or where more detailed information on the standard achieved by the trial layout is desired.

(h) If the desired values are not achieved, further adjustment of the luminaire spacing or mounting height, or selection of an alternative luminaire or lighting arrangement, or a combination of these measures, may be necessary until an acceptable design is produced.

10.2 MINIMUM DESIGN AREAS FOR APPLICATION OF ILLUMINANCE REQUIREMENTS TO SPECIFIC ROAD SITUATIONS

Minimum design areas for the application of illuminance requirements to specific road situations are set out in the design rules of Section 3 of AS/NZS 1158.1.1.

10.3 LIGHTING LAYOUTS

10.3.1 Indicative lighting layouts

Indicative lighting layouts for specific road situations are illustrated in Appendix F. These layouts may be used for initial design of a lighting scheme but not to negate the need for lighting schemes under consideration for the particular roads to be evaluated in accordance with AS/NZS 1158 Part 1.1 and Part 2 to satisfying compliance requirements.

10.3.2 Factors influencing the lighting layout

The following factors may influence the layout and design of a lighting installation:

(a) *Nature of abutting development* This will influence selection of the appropriate lighting category, the lighting design in terms of luminaire type, arrangement and mounting height, and aspects such as glare control and spillage of light into sensitive areas.

(b) *Form of the road cross-section* This influences the lighting arrangement, i.e. single-sided, opposite, central or staggered.

(c) *Width of the carriageway and their relative levels* This will influence the arrangement of luminaires and mounting height.

(d) *Nature of horizontal and vertical alignment* The spacing of luminaires may need to be varied on curves and crests to achieve the optimum performance of the installation.

(e) *Form and location of intersections* Intersections are critical locations that may require special treatments, poles, luminaires and mounting heights to achieve the required lighting performance and to minimize traffic collisons with lighting poles.

(f) *Location of bus/tram stops and other points of concentration of pedestrian movement across the road* The positioning of luminaires relative to these points will be important in achieving the desired standards of traffic safety and pedestrian security.

(g) *Location of driveways/entrances, median and separator openings (in multi-carriageway roads) and underground services* These will impose limitations on the positioning of lighting poles and the choice of pole types.

(h) *Width of nature strip and footpath and of medians, separators and traffic islands in which poles may be located* These will influence the choice of pole type and bracket arm length.

(i) *Location and nature of overhead power distribution* This may influence the choice of lighting arrangements, e.g. use of existing power poles to support luminaires. The nature of the power lines may impose limitations on the mounting height and on the positioning of lighting poles, particularly poles of the frangible type.

(j) *Location and form of any traffic management devices* When traffic management devices such as speed modification zones or pedestrian safety zones are installed on roads that require Category V lighting, special attention will need to be given to ensuring satisfactory visibility of these devices.

(k) *Presence, type and locations of trees within the road reserve* This may influence the choice of lighting arrangement, and the locations and mounting heights of luminaires.

10.3.3 Evaluation of alternative layouts

Where a number of alternative arrangements are possible, each should be prepared in sufficient detail to establish a reasonable estimate of the cost of installation, operation and maintenance. In addition, a comparative evaluation of the alternative arrangements should be made if there are significant differences in lighting performance. The alternative arrangements may be compared on the basis of the following attributes:

(a) *Lighting performance* This may be compared in terms of the light technical parameters achieved generally along the route, or by the use of a broad measure of lighting level (i.e. total flux/spacing H road width).

(b) *Route guidance* The ability of the lighting layout, as seen in perspective, to enhance the driver's appreciation of the run of the road ahead and the location and nature of the discontinuities, such as sharp curves or changes in cross-section, is an important attribute of a road lighting installation. This may be assessed subjectively, based on experience of known installations in similar conditions or, in complex situations (e.g. through large channelized intersections or roundabouts), by the use of scale models or computer techniques for perspective drawing.

(c) *Economics* Economic comparisons between the alternative arrangements may be made in terms of one or more of the following:

    (i) Capital costs.

    (ii) Running costs.

    (iii) Annual costs per kilometre of route lit.

    An important issue affecting capital and running costs is the consideration of energy efficiency. Energy requirements of the lighting installation may be reduced by selecting the more energy efficient lamps (more lumens per watt in the desired visual spectrum), the more accurate and reliable of the available switching devices, the luminaire flux distribution that is more appropriate for the installation geometry, high power factor control equipment, low circuit impedance of supply cables, supply voltage within close tolerances of lamp voltage rating, and by specifying lower limits of allowable luminaire and lamp depreciation over the maintenance interval.

(d) *Road safety aspects* (See Clauses 2.3 and 7.2.)

(e) *Environmental considerations* (See Clause 7.3.)

(f) *Aesthetic considerations* (See Clause 7.11.)

10.4 ELECTRICAL DESIGN

The electrical works form an important and integral part of a road lighting design. The lighting tariff under which the lighting is to be installed will influence the choice of equipment (which will directly affect the lighting design) and funding for the installation. The first priority of the electrical circuit design is to minimize the adverse effects of any faults on the performance of the lighting system. To this end—

(a) each luminaire should be individually protected; and

(b) luminaires should be appropriately allocated to particular circuits.

On straight sections, luminaires should be connected to lighting circuits in sequence of phase rotation. Care should be taken, especially at intersections, to ensure that in the event of a circuit fault, misleading visual guidance is not given.

Other aspects of the electrical design that may need to be addressed/provided are as follows:

(i) The road lighting authorities' equipment standards, maintenance requirements and supply particulars.

(ii) Where appropriate, lighting circuits should be designed and optimized, taking into account cable routes, types, and sizes, and where applicable, voltage drop and earth resistance calculations (see AS/NZS 3000).

(iii) The method of switching to be used, e.g. switching at each luminaire or from a central point (see Clause 13.2.).

(iv) If voltage drop calculations and cable sizing has been taken into account, whether power factor correction capacitors will be installed.

(v) Where appropriate, switchboard circuit schedules should be produced indicating, per circuit, details such as switchboard number, cable, circuit and neutral number, luminaire identification, combined load current, run and start currents, circuit-breaker ratings, conductor size.

(vi) Where appropriate, switchboard details should be specified identifying details such as type of switchboard (e.g. pole-mounted, plinth-mounted), number of phases/circuits, circuit protection ratings or mode of power switching (e.g. time clock, daylight switch, pulse or a combination).

(vii) Three phase circuits should be balanced for phase currents.

(viii) Sharing of facilities with other systems and possible future systems should be investigated, i.e. if using joint-use poles, is it possible for lighting circuits to share traffic signal ducting or road crossings.

10.5 CIVIL/STRUCTURAL WORKS

A number of factors relating to the civil/structural works associated with a lighting design may need to be addressed, such as the following:

(a) Pole locations and types should be determined in accordance with the relevant road authorities' policies with due regard to possible collisions by errant vehicles.

(b) Structural integrity of the lighting poles and bracket arms and compliance with relevant standards.

(c) Pole or service relocations should be planned and documented, and should be scheduled to proceed in a timely manner so as not to adversely affect the installation of the road lighting.

(d) Where appropriate, ducting routes should be determined detailing ducting size and type. Reference should be made to the relevant authority for cable burying depths.

(e) Where appropriate, pit sizes and locations should be detailed together with lid types (e.g. steel for the passage of vehicles) and other protection and drainage details.

(f) Where appropriate, pole footing details should be provided.

10.6 LIGHTING DESIGN AUDIT

The objective of the road lighting design should be to ensure the relevant light technical parameters comply with the limits specified in Section 2 of AS/NZS 1158.1.1 for the selected lighting category, and give consideration to the road environment, lamp lumen depreciation and maintenance practices.

The lighting performance of as-designed installations should be checked by an independent designer, using the same luminaire positions and installation geometry, and separately entering the luminaire photometric data into the appropriate software for calculations of luminance and illuminance. Tabulations of the light technical parameters and isolux diagrams may then be produced and compared to the original design to verify conformity or otherwise with the requirements of AS/NZS 1158.1.1.

The audit, while testing compliance with AS/NZS 1158.1.1, does not assess the capability of the selected luminaire to provide for a more economical spacing. However, relatively high illuminances may signal the need for a redesign, depending on physical constraints to pole placement and the limited choice of luminaires.

The audit process should include a check that the design layout of the lighting scheme is compatible with the physical details of the intended site to reduce the potential need for costly remedial works at a later date.

SECTION 11 DOCUMENTATION

11.1 EVIDENCE OF COMPLIANCE

The design of the lighting scheme is deemed to comply with the requirements of AS/NZS 1158.1.1 if, when created in accordance with the relevant procedures of that Standard, it satisfies the light technical parameters of AS/NZS 1158.1.1, Table 2.2 at all times throughout its projected life (see AS/NZS 1158.1.1, Clause 2.11).

At the completion of the design, information shall be supplied by the designer to the client for acceptance as per AS/NZS 1158.1.1 (Clause 2.11).

NOTE: Also see Appendix D.

11.2 ESTIMATES AND MATERIAL LISTS

Estimates and material lists, where required, are used to cost schemes and to order materials, and consist of the following:

(a) Estimates include labour costs, materials costs and on-costs.

(b) Material lists include the numbers and types of materials required to carry out the job for ordering purposes and costing.

SECTION 12 INSTALLATION

12.1 STANDARDS, REGULATIONS AND OTHER REQUIREMENTS

Road lighting should be installed in accordance with applicable standards, regulations and other requirements, such as those listed below:

(a) The performance and installation design requirements of AS/NZS 1158.1.1.

(b) The use, where necessary, of underground marking tape complying with AS/NZS 2648.1.

(c) The installation of electrical wiring in accordance with AS/NZS 3000.

(d) Relevant specifications issued by the road controlling authority.

(e) Relevant policies and standards of the road controlling authority.

(f) Relevant policies and technical standards of the electricity supply authority.

(g) Relevant electrical safety standards.

12.2 INSTALLATION AUDIT

12.2.1 Audit process

A road lighting audit constitutes a formal examination of an existing/new road lighting installation in which an independent, qualified examiner looks at the road lighting installation. This results in the production of a formal report.

The objectives of a road lighting audit are to—

(a) ensure the installation has been constructed according to the design;

(b) to provide a statement of 'as built verification' (see AS/NZS 1158, Part 1.1, Clause 2.11);

(c) ensure the installation conforms to the relevant authority's standards and policies; and

(d) identify potential safety problems for road users and others that may be affected by the road lighting installation.

The benefits of a road lighting audit include the following:

(i) Reduced need for costly remedial works at a later date.

(ii) Reduced likelihood and severity of crashes.

(iii) Greater prominence of road safety in the minds of road lighting designers.

The attainment of benefits from the audit process are contingent upon both strong support and commitment to road lighting/safety audit principles and objectives by senior management and the independence of the audit team. The latter requirement is necessary to ensure the procedure is objective.

12.2.2 Audit check list

12.2.2.1 *Luminaires*

The following checks should be made relating to the road lighting luminaires installed:

			Initial	Date
(a)	Has the correct luminaire been installed?	Yes/No	_____	__/__/__
(b)	Has the correct lamp been installed (e.g. type, external ignitor)?	Yes/No	_____	__/__/__
(c)	Has the correct lamp control gear been used?	Yes/No	_____	__/__/__
(d)	Has the floodlight been aimed correctly?	Yes/No	_____	__/__/__

12.2.2.2 *Poles*

The following checks should be made relating to the lighting poles installed:

			Initial	Date
(a)	Has the correct type of pole been installed (e.g. buried-in-ground, baseplate-mounted, slip-base, energy-absorbing, timber, steel)?	Yes/No	_____	__/__/__
(b)	Has the correct outreach arm been installed (e.g. length, uplift, spigot, upcast angle)?	Yes/No	_____	__/__/__
(c)	For slip-base poles, has the correct torque been applied to the anchor cage holding down bolts and the slip-base clamping bolts?	Yes/No	_____	__/__/__
(d)	Is the clearance between the ground and the slipbase flange not greater than that allowable?	Yes/No	_____	__/__/__

12.2.2.3 *Road lighting design*

The following checks should be made relating to the road lighting design:

			Initial	Date
(a)	Has the design mounting height been achieved?	Yes/No	_____	__/__/__
(b)	Has the designed overhang been achieved?	Yes/No	_____	__/__/__
(c)	Has the designed spacing been achieved?	Yes/No	_____	__/__/__
(d)	Have any variations to the design been checked with the designer for compliance with AS/NZS 1158.1.1?	Yes/No	_____	__/__/__

12.2.2.4 *Power supply*

The following checks should be made relating to the power supply:

			Initial	Date
(a)	Has the power been supplied appropriate to the pole type (e.g. slip-base poles cannot be supplied via overhead conductors)?	Yes/No	_____	__/__/__
(b)	Has the correct power cable been installed (e.g. type, size)?	Yes/No	_____	__/__/__
(c)	Have luminaire terminal panels been used where appropriate?	Yes/No	_____	__/__/__
(d)	Have the correct cable joints been used?	Yes/No	_____	__/__/__
(e)	Has the correct switchboard/junction box/pole fuse termination been employed?	Yes/No	_____	__/__/__
(f)	Does the mains connection conform with the relevant authority's policy/practices?	Yes/No	_____	__/__/__

12.2.2.5 *Installation geometry*

The following checks should be made relating to the installation geometry:

			Initial	Date
(a)	Have the appropriate installation practices/policies been adopted (e.g. use of pits, wiring, terminations)?	Yes/No	_____	__/__/__
(b)	Has the finished installation been checked to verify total compliance to the lighting design?	Yes/No	_____	__/__/__

12.2.2.6 *Civil works*

The following checks should be made relating to the civil works:

			Initial	Date
(a)	Has the correct electrical conduit been installed (e.g. type, size)?	Yes/No	_____	__/__/__
(b)	Has a draw rope been installed within the electrical conduit?	Yes/No	_____	__/__/__
(c)	Has the electrical conduit been installed at the correct depth for its location?	Yes/No	_____	__/__/__
(d)	Has the correct underground marking tape been installed?	Yes/No	_____	__/__/__
(e)	Has the correct electrical pit been installed (e.g. type, size, pit lid type)?	Yes/No	_____	__/__/__
(f)	Has the electrical pit been installed correctly?	Yes/No	_____	__/__/__
(g)	Has the electrical pit been installed at the correct location?	Yes/No	_____	__/__/__
(h)	Have pit surrounds been installed?	Yes/No	_____	__/__/__
(i)	Have the correct trenching/excavation/backfill practices been employed (e.g. electrical conduit, footings)?	Yes/No	_____	__/__/__
(j)	Has drainage been correctly addressed?	Yes/No	_____	__/__/__

12.2.2.7 *Road lighting footings*

The following checks should be made relating to the road lighting footings:

(a)	For baseplate-mounted poles, has the correct anchor cage been installed (e.g. length appropriate to soil type, pole type)?	Yes/No	_____	__/__/__
(b)	For baseplate-mounted poles, has the correct electrical conduit been installed in the footing?	Yes/No	_____	__/__/__
(c)	For baseplate-mounted poles, has the correct conduit been installed in the correct location?	Yes/No	_____	__/__/__
(d)	For buried-in-ground poles, has a concrete collar been correctly installed?	Yes/No	_____	__/__/__
(e)	Have correct installation practices/policies been employed (e.g. concrete strength, footing size, formwork)?	Yes/No	_____	__/__/__

12.2.2.8 *Documentation*

A check should be made that the installation conforms with 'as constructed' drawings and the record of the installation is able to be verified for accounting, operation and maintenance purposes. Yes/No _____ __/__/__

12.2.2.9 *Workplace health and safety requirements*

In the process of in situ inspections, survey work and site inspections, care was taken to observe the requirements of the road authority working on roadways, including the use of temporary signs, devices and traffic controllers. Yes/No _____ __/__/__

12.2.2.10 *Control devices*

The following checks should be made relating to control devices.

(a) Photocells are positioned in safe locations. Yes/No _____ __/__/__

(b) Photocells are correctly installed so as to avoid direct/reflected light. Yes/No _____ __/__/__

(c) Photocells are correctly orientated. Yes/No _____ __/__/__

(d) Photocells are operating/switching correctly. Yes/No _____ __/__/__

(e) Circuits are not loaded above the rating of the switching device. Yes/No _____ __/__/__

(f) Time switches are tested for correct operation and settings. Yes/No _____ __/__/__

SECTION 13 OPERATION

13.1 HOURS OF OPERATION

Lighting on traffic routes should operate all night, nominally from dusk to dawn, as the incidence of road crashes at night is not solely related to variations in traffic volume. In this respect, although traffic density decreases late at night, the probability of serious crashes (occasional vehicle with occasional vehicle and occasional vehicle with occasional pedestrian) tends to increase (see Clause 13.3).

Provision for the lighting of traffic routes during periods of poor light conditions, e.g. during a storm or in fog, should be addressed (see Clauses 13.2 and 13.3).

13.2 SWITCHING CONTROL

The switching of road lighting should always be related to sunrise and sunset. Throughout the year, under clear sky and fine weather conditions, an 'on' time of approximately 15 min after sunset and an 'off' time of approximately 15 min before sunrise is recommended for the particular locality concerned.

The switching of road lighting may be effected by any of the following methods, or by a combination thereof:

(a) *Photoelectric switching* Photoelectric control devices should be set to switch the lighting on at daylight illumination levels greater than the illuminance provided on the carriageway by the road lighting. This will allow lamps, which are now most commonly of the discharge type, to 'run-up' and attain full operating luminous output.

(b) *Centralized remote control* Where local switching devices are operated from a central point by:

    (i) Ripple relay switching by the injection of a high frequency 'ripple' signal into the electricity distribution system.

    (ii) Cascade (switchwire) switching by the application of a control voltage through supervisory cables, pilot cables or the adjacent electricity distribution system section.

    (iii) Radio switching operated by emerging central management systems.

    Initiation of the switching can be by any of the means described in Items (a), (c) or (d).

(c) *Time switches* Electrically operated time switches having a mechanical spring reserve should be used, with an astronomical-dial automatic adjustment for seasonal variations of sunrise and sunset.

(d) *Manual switching* Because of the element of chance introduced by the human factor, this method is not generally used except for special situations or as a manual back up or bypass to Items (a), (b) or (c) controlling luminaires on switched circuits.

A switch-on level of between 15 lx and 30 lx is recommended. In the temperate climatic zone the lower switch-on level of 15 lx is satisfactory, but for the tropical zones with their shorter twilight the upper value of 30 lx should be selected. The illuminances recommended refer to the conditions produced by a cloudless, unobstructed sky on a horizontal surface.

NOTES:

1 It is desirable for the switch-off level to be less than the switch-on level because the latter includes provision for lamp warm-up time. Photoelectric controls that utilize photodiode/ phototransistor electronic light sensors, are available for inverse light level switching. The switching characteristics of historically commonly used cadmium sulphide sensor photoelectric control devices are such that their switch-off levels are approximately 2 to 3 times the switch-on level.

2 The switching times of photoelectric equipment will be approximately the same as those recommended for time switches under fine, clear-sky weather conditions. However, under conditions reducing the ambient light levels including adverse weather conditions or luminaires shaded by trees or adjacent buildings, the photoelectric equipment could switch on up to 20 min earlier and switch off up to 30 min later.

13.3 ADVANCED CENTRAL ROAD LIGHTING CONTROL SYSTEMS

13.3.1 General

Centralized electronic remote road lighting control systems that monitor lighting schemes as a whole and each individual point have become available. These systems can switch lighting and dim or adapt lighting levels, as separate or comprehensive systems.

13.3.2 Switching of lighting

The lighting schemes in an area may be switched on and off via one photocell monitor. A single selected, calibrated cell will ensure the switching of all lighting at the same time. Advantages include that lighting is switched at the optimum times, the installation and maintenance of multiple cells is unnecessary, the reduction of 'day' burners as existing cells fail safe.

13.3.3 Dimming or adapting lighting

Lighting schemes may be dimmed or adapted to change the lighting level according to prevailing conditions. Lighting schemes may be dimmed according to road usage. The normal lighting subcategory is selected for a particular lighting scheme on the basis of the most demanding operating characteristics of that road. The application of this subcategory may not be justified throughout all the hours of darkness because of much lower road usage through some hours. The dimming of lighting will lower the overall level of lighting without changing the lighting uniformity. The lighting, when dimmed should meet the light technical requirements of a lower subcategory. Switching of some luminaires is not recommended since the quality criteria will be seriously impaired.

Any decision to use adaptive lighting should be carefully justified. A blanket application to a large area for certain hours for each weekday will generally not be warranted. Factors to take into account include variation of traffic, vehicular and pedestrian, by hour and day of the week; vehicle speed; standard of road geometry.

Where the pattern of variation in parameter values is well known, such as from a record of traffic counts on traffic routes, or can be reasonably assumed, as in many residential areas, a simple time-based control system may be appropriate. In other situations an interactive control system linked to real-time data may be appropriate to monitor conditions. This approach will also permit the normal lighting subcategory to be activated in the case of road works, serious crashes, bad weather or poor visibility.

Category V lighting has been shown to be an effective night crash counter. However because the lighting levels for the majority of measure schemes are relatively modest, reduction in lighting level dimming may nullify the counter measure to an extent. For these reasons there should be consultation between all parties, service providers, their clients, road authority and police on any proposed use of adaptive lighting.

SECTION 14 ASSET MANAGEMENT MAINTENANCE

14.1 GENERAL PURPOSE

Asset Management maintenance strategies and procedures should be established so that road lighting schemes continue to operate safely, efficiently and effectively over their economic life. Compliance of lighting performance is deemed to be achieved if the maintenance strategies and procedures adopted for a road lighting scheme designed in accordance with AS/NZS 1158.1.1 ensure the following lighting technical parameters do not fall below the relevant maintained values specified in AS/NZS 1158.1.1:

(a) The maintained average carriageway luminance, $\overline{L}$.

(b) The maintained point illuminance at intersections, E_{Ph}.

14.2 FACTORS AFFECTING PERFORMANCE

The performance of road lighting installations is affected by two distinct processes, namely—

(a) lamp failures or outages caused by the failure of other equipment (see Clause 14.3); and

(b) the progressive reduction in light output of the lamp/luminaire combination (see Clause 14.4).

Maintenance strategies should be included in an overall Asset Management maintenance program so there is a timely response to replace lamps, and repair/replace other equipment that has failed in service, and so luminaires are cleaned or replaced and lamps are replaced before the light output of each lamp/luminaire unit falls below the level needed to ensure the relevant maintained values of $\overline{L}$ and E_{Ph} are maintained.

14.3 LAMP OUTAGES

14.3.1 General

Lamp outages may occur because of failure of the equipment items comprising the lighting installation, or failure of the electricity supply caused by the breakdown of equipment, accidental or malicious damage, lightning and storm damage and the corrosive effects of the environment.

Although experiences of lamp outages may differ somewhat between road lighting authorities, the high proportion of outages attributed to lamp failures is supported by manufacturers' data on lamp mortality rates (see Appendix E). Particular consideration should be given to lamp failures in establishing an effective maintenance program.

A comprehensive maintenance record system that contains information about the frequency of lamp outages and the reasons for such outages, including the incidence of the various equipment component failures, will assist in the development of strategies for improved service availability. The requirements of a maintenance records system are given in Clause 14.5.8.

Information to assist in identifying common faults resulting in non-operation or incorrect operation of high pressure sodium vapour lamps and high pressure metal halide lamps is given in Tables 14.1 and 14.2 respectively. Figure 14.1 sets out a flow chart to help determine appropriate remedial action.

TABLE 14.1

GUIDE TO FAULTS WITH HIGH PRESSURE SODIUM LAMPS

Problem	Possible cause	Corrective maintenance and remarks
Lamp cycles on-off-on-off	End of useful lamp life	Install a new lamp This is the first sign of end of lamp life. As a high pressure sodium lamp is burned for long periods, the lamp operating voltage tends to increase. This voltage rise reaches a level where the ballast cannot sustain the lamp. When this point is reached (approximately 4 to 5 years, if supply voltage lies within normal tolerances*), the lamp will exhibit a cycling on and off characteristic. When cycling of the lamp starts, the on-time is about 2 h. This on-time will reduce if left in service down to 5 min. The off-time is about 3 min A cycling lamp left in service will cause ignitor failures. The use of timed ignitors in luminaires should be considered to assist in minimizing igniter failure from a cycling lamp.
	Stray light on PE switch	Stray light from adjacent luminaires, car headlights or reflected light can cause cycling (on 3 min-off 3 min).
Lamp will not start	End of lamp life	Install a new lamp. The lamp fails in one of the following ways: arc tube ruptured, blackened or swollen arc tube, burnt off or failed arc tube connecting ribbons or blackened outer envelope.
	Lamp loose in holder	Inspect lampholder to see if there is any indication of arcing at the contacts. Tighten lamp to seat it properly. In situations where the luminaire is subjected to higher levels of vibration, i.e. on bridges or exposed locations, the use of special lampholders in luminaires to minimize the effects of vibration maybe considered.
	No supply to lantern No supply to control gear	Restore supply from mains. Check luminaire fuse, circuit breaker or circuit controlling contactor, if fitted.
	Defective controlgear	Install a new luminaire and lamp, or replace control gear. Workshop test and inspection: The HPS lamp requires high voltage (typically 4.5 kV) to start the lamp. Use an approved ignitor tester to check that an appropriate voltage pulse is delivered. Visual inspection and continuity testing should detect other control gear defects.
	Lamp has been operating: cool down time insufficient, (hot restrike)	The HPS lamp requires up to 3 min cool down time to re-establish starting conditions after they have been operating and the supply is switched off or interrupted.
Short lamp life	Normal failures	Early failures can be expected in any normal batch of lamps. See lamp mortality data for the particular lamp used where there is doubt as to lamp life performance.
	Premature failures	Short lamp life will be experienced if HPS lamps are subject to any of the following line supply conditions: Overvoltage (supply should lie within normal tolerances*), spikes, HV injections, surges or lightning strikes. Short lamp life can also be experienced if the lamps are subject to severe vibration or impact.
Ballast or ignitor failed	Broken welds or fatigue fractures of metallic conductors within lamp	Install new lamp or thoroughly check existing lamp for integrity of internal metallic conductive parts. Momentary interruption of arc current due to intermittent connections within the lamp can result in lamp circuit auxiliary devices being subjected to currents or voltages in excess of those for which they are designed.

* In Australia, the normal tolerance range for the supply is 230 V +10% −6%. In New Zealand, the normal tolerance range is 230 V ±6%.

NOTE: The above details assume the lamps are connected to the correct control gear and circuit.

TABLE 14.2

GUIDE TO FAULTS WITH HIGH PRESSURE METAL HALIDE LAMPS

Problem	Possible cause	Corrective maintenance and remarks
Lamp will not start	End of lamp life	Install a new lamp The lamp fails due to mechanical defects in the lamp.
	Lamp loose in holder	Inspect lampholder to see if there is any indication of arcing at the contacts. Tighten lamp to seat it properly.
	No supply to lantern No supply to control gear	Restore supply from mains. Check luminaire fuse, circuit breaker or controlling circuit contactor, if fitted.
	Defective controlgear	Install a new luminaire and lamp Workshop test and inspection Visual inspection and continuity testing should detect control gear defects.
	Lamp has been operating: cool down time insufficient, (hot restrike)	The metal halide lamp requires a period of from 4 min to 8 min cool down time to re-establish starting conditions after they have been operating and the supply is switched off or interrupted.
Short lamp life	Normal failures	Early failures can be expected in any normal batch of lamps. See lamp mortality data for the particular lamp used where there is doubt as to lamp life performance.
	Premature failures	Shorter lamp life could be experienced if metal hlaide lamps are subject to any of the following line supply conditions: Overvoltage (supply should lie within normal tolerances*), spikes, HV injections, surges or lighting strikes. Short lamp life can also be experienced if the lamps are subject to severe vibration or impact.
Lamp cycles on-off-on-off	Stray light on PE switch	Stray light from adjacent luminaires, car headlights or reflected light can cause cycling (on 2 min, off 4 min to 8 min).
	Low supply voltage	Check supply voltage to luminaire. Ensure supply cabling size is sufficient for load. Metal halide lamps are more susceptible to supply voltage fluctuations than HPS or HP Mercury Vapour.
	Loose wiring connections	Check wiring connections are tight.

* In Australia, the normal tolerance range for the supply is 230 V +10% −6%. In New Zealand, the normal tolerance range is 230 V ±6%.

NOTE: The above details assume the lamps are connected to the correct control gear and circuit.

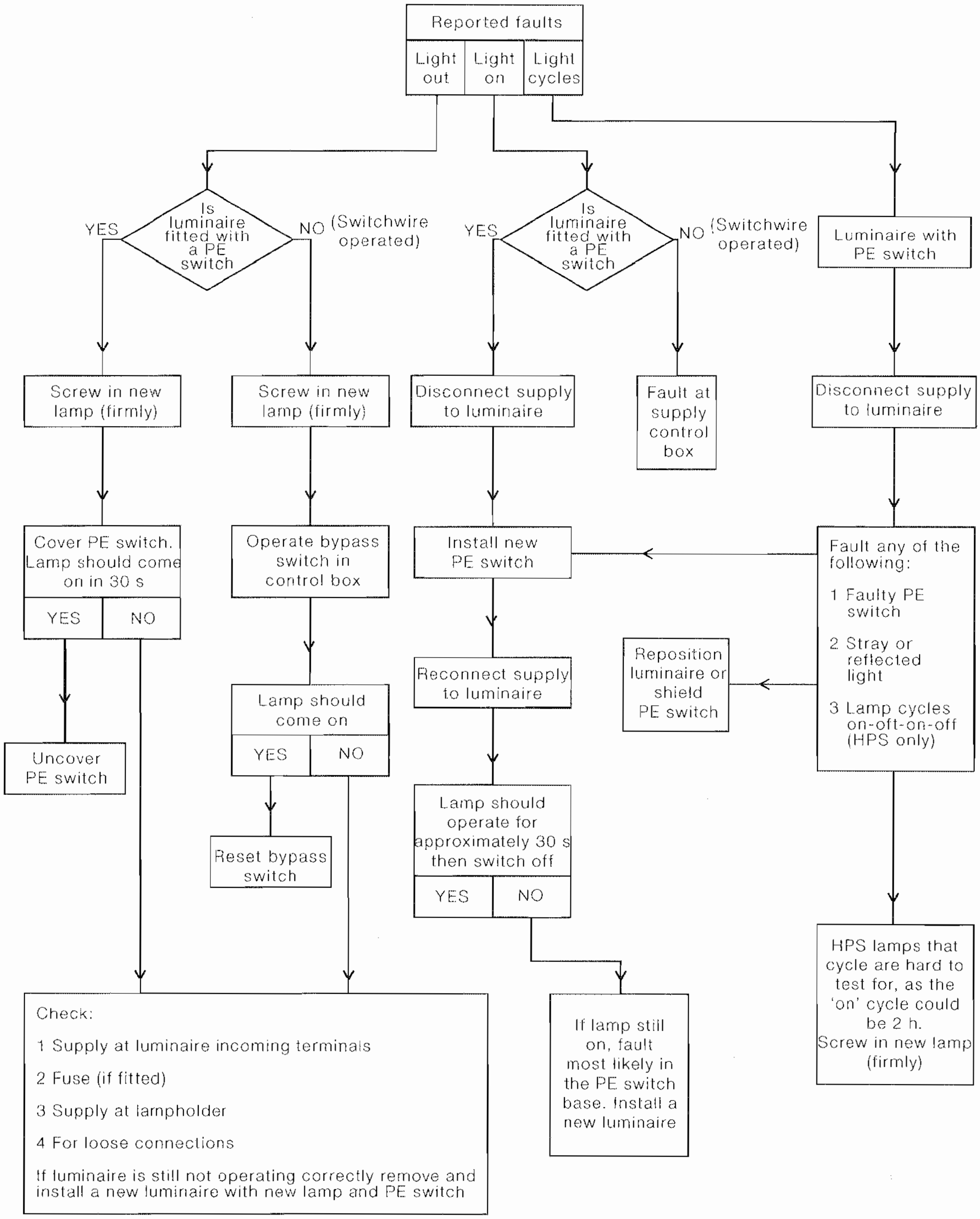

Reported faults
Light out
Light on
Light cycles
Is luminaire fitted with a PE switch
YES
NO (Switchwire operated)
Is luminaire fitted with a PE switch
YES
NO (Switchwire operated)
Luminaire with PE switch
Screw in new lamp (firmly)
Screw in new lamp (firmly)
Disconnect supply to luminaire
Fault at supply control box
Disconnect supply to luminaire
Cover PE switch. Lamp should come on in 30 s
YES
NO
Operate bypass switch in control box
Install new PE switch
Fault any of the following:
1 Faulty PE switch
2 Stray or reflected light
3 Lamp cycles on-off-on-off (HPS only)
Reposition luminaire or shield PE switch
Reconnect supply to luminaire
Uncover PE switch
Lamp should come on
YES
NO
Reset bypass switch
Lamp should operate for approximately 30 s then switch off
YES
NO
HPS lamps that cycle are hard to test for, as the 'on' cycle could be 2 h. Screw in new lamp (firmly)
Check:
1 Supply at luminaire incoming terminals
2 Fuse (if fitted)
3 Supply at lampholder
4 For loose connections
If luminaire is still not operating correctly remove and install a new luminaire with new lamp and PE switch
If lamp still on, fault most likely in the PE switch base. Install a new luminaire

FIGURE 14.1 GUIDE TO REMEDIAL ACTION FOR LUMINAIRES WITH HIGH PRESSURE DISCHARGE LAMPS

14.3.2 Lamp failures

The manufacturer's data on lamp mortality rates is derived from laboratory tests in a controlled environment, and as such, can be taken as a general guide to the frequency of lamp replacement when considered in conjunction with lamp lumen depreciation data.

NOTE: Typical mortality curves for selected lamp types and ratings are shown in Appendix E. These illustrate representative lamp performance based on manufacturer's data. The reliability of the curves decreases as the number of burning hours increases.

In practice, lamp life is affected by a number of factors including the type of ballast, ambient temperature, operating voltage, voltage fluctuations, frequency of switching, the lamp burning position, the amount of vibration transmitted from the pole and outreach bracket and vandalism.

High pressure sodium lamps are more prone than other discharge lamps to exhibit cycling or intermittent operation in the failure mode.

14.3.3 Photoelectric (PE) switch failure

Photoelectric switches age in service and a replacement program may need to be developed for economic management of these components. Consideration may be made of including PE switch replacement in-conjunction with a lamp replacement program for economic efficiencies.

Electronic light sensor PE switches, which typically incorporate photodiodes or phototransitors, and are now typically the most commonly used PE switch type, should normally be expected to have a minimum service life of around 8 to 10 years, provided that voltage surges and temperature do not exceed the ratings. Other forms of PE switches (i.e. cadmium sulphide cells) tend to drift in switching performance whereas electronic light sensor PE switches are more stable in this regard, although they are more sensitive to voltage surges and higher temperatures.

For safety reasons, the PE switches used should be typically of the type that when they become non-operational they are designed to remain in the 'on' position. Any non-operational PE switches should be replaced under maintenance strategies similar to that for lamp replacements (Clause 14.5.3).

Disposal of PE switches after they have been removed from service should be undertaken in a safe and environmentally acceptable manner, having regard to any regulations or requirements of the appropriate authorities.

14.4 LAMP AND LUMINAIRE DEPRECIATION

14.4.1 Lamp depreciation

During the life of a lamp there is a gradual deterioration in light output, or lamp lumen depreciation, caused by the normal ageing process and influenced by manufacturing tolerances, environmental factors and operating conditions, as discussed in Clause 14.3.1.

Some typical lamp lumen depreciation curves, based on manufacturers' data for selected lamp types, are shown in Appendix E. It will be observed that different rates of depreciation are obtained for different lamp types, and the serviceable burning hours will be dictated by the allowable depreciation, with consideration given to the required initial output and the allowable luminaire depreciation.

Due to the variation in lumen output of lamps, when new the manufacturer's published lumen output for lamps having completed a 'burning-in' period of 100 hours is deemed to be the 'initial' lumen output. This method of lumen output determination is the more reliable initial performance figure on which to calculate percentage depreciation to determine the lamp change interval.

14.4.2 Luminaire depreciation

Light output from the luminaire gradually reduces as the luminaire ages and deteriorates under service operating conditions. This can be caused by dirt and dust collecting on reflecting surfaces, the ingress of insects and moisture through the failure of seals, the loss of transparency of the visor through the accumulation of dirt, dust and pollution on both external and internal visor surfaces, and visor discolouration caused by sunlight, heat and the effects of ultra violet light from the lamp itself. The severity of fouling will depend on the design of the luminaire including Ingress Protection rating, visor self-cleaning effectiveness during rainy weather, use of external reflecting surfaces (e.g. some decorative luminaires), and the amount of pollution present in the atmosphere.

Luminaires with a lamp chamber with a higher Ingress Protection rating against dirt, dust and pollution i.e. 6X will optically perform better and have a slightly lower luminaire depreciation than a luminaire with lamp chamber with a lower Ingress Protection i.e. IP5X. The use of luminaires with the higher Ingress Protection rating is recommended.

Luminaire cleaning will usually regain the light output lost due to luminaire depreciation. However gradual permanent depreciation in reflectivity of reflectors, the transparency of visors and the effectiveness of Ingress Protection seals will all contribute to determining the effective service life of the luminaire.

Cleaning intervals should be determined based upon the factors contributing to the severity of fouling, including the luminaire design, Ingress Protection rating and site conditions, although, for economic reasons, cleaning may be carried out in conjunction with lamp replacement, provided the overall lumen output of the lamp/luminaire combination does not fall below that necessary to ensure compliance with the applicable maintained values $\overline{L}$ and E_{Ph}.

14.4.3 Allowances for lamp and luminaire depreciation

The specification in AS/NZS 1158.1.1, of maintained values of the light technical parameters, requires that appropriate allowance be made for the combined light losses resulting from depreciation in both the lamp and luminaire output over the nominated maintenance period.

The combined depreciation in light output is called the *Maintenance Factor* (MF) and is used in the design calculations of a road lighting scheme to ensure compliance with the specified light technical parameters.

The *Maintenance Factor* derived to allow for the combined light loss is calculated as the product of the following:

(a) *Luminaire maintenance factor* The factor selected from Table 14.4 applicable for the luminaire lamp chamber Ingress Protection rating, pollution category, and luminaire cleaning interval.

(b) *Lamp lumen depreciation factor* The lamp luminous flux available at the end of the nominated maintenance period, as a proportion of the initial lamp luminous flux, expressed as a decimal fraction.

NOTE: Typical lamp lumen depreciation data for lamps applicable to Category V lighting are given in Appendix E.

Example:

The luminaire maintenance factor for a luminaire installed in a high pollution area, with a lamp chamber Ingress Protection rating of IP6X, and a maintenance cleaning interval of 24 months (approximately 8400 h lamp burning time) is 0.88, as taken from Table 14.4.

The lamp lumen depreciation factor for a high pressure sodium vapour lamp operated for 8400 h, taken from Figure E1 in Appendix E, is 0.92.

The total Maintenance Factor is a product of the two separate factors, i.e. 0.88 × 0.92 = 0.8.

TABLE 14.4

TYPICAL LUMINAIRE MAINTENANCE FACTORS

Cleaning interval	Typical luminaire maintenance factors (Note 1)					
	Ingress Protection Number of Lamp Chamber					
	IP54			IP6X		
	Pollution category (Note 2)					
months	High	Medium	Low	High	Medium	Low
12	0.89	0.90	0.92	0.91	0.92	0.93
18	0.87	0.88	0.91	0.90	0.91	0.92
24	0.84	0.86	0.90	0.88	0.89	0.91
36	0.76	0.82	0.88	0.83	0.87	0.90
48	0.66	0.76	0.86	0.75	0.84	0.89

NOTES:

1 The effects of lamp lumen depreciation are not included in the luminaire maintenance factors.

2 The luminaire maintenance factors are based on an ingress protection rating of IP54 and IP64 in accordance with AS 60529 for the lamp chamber, as required by AS/NZS 1158.6. The values of luminaire maintenance factor are based on those given in BS 5489-1:2003 with those for a 48 month cleaning interval being an extrapolation of that data set. Further extrapolation by cleaning interval is not recommended.

3 High pollution applies for the centres of large urban areas and for heavy industrial areas. Medium pollution applies for semi-urban, residential and light industrial areas. Low pollution applies for outer residential, rural areas.

AS/NZS 1158.1.1 permits a maintenance factor up to 0.8 to be used in lighting calculations. Consequently, in the above example, a maintenance factor of 0.8 would be assumed.

If the nominated maintenance period results in a maintenance factor of 0.8 or greater, then the installation should ensure compliance with the maintained values of $\overline{L}$ and E_{Ph} required in Section 2 of AS/NZS 1158.1.1, even if it is designed at or close to the minimum initial values that are required for those parameters.

If the nominated maintenance period results in a maintenance factor of less than 0.8 (e.g. 0.6) then this maintenance factor can only be used if the initial design values $\overline{L}$ and E_{Ph} are increased in the ratio—

$$\frac{0.8}{\text{actual maintenance factor}}, \text{ e.g. } 0.8/0.6.$$

Some flexibility is thereby provided for adjustment of the road lighting design, by appropriate selection of the initial design values and lamp replacement and luminaire cleaning intervals, to optimize the design based on life cycle costs.

The resulting maintenance regime and its implementation then becomes an essential component of continuing compliance of the lighting performance requirements through the life of the lighting scheme. It is therefore essential the maintenance regime requirements are developed in consultation with the responsible road lighting authority and operator as an integral part of the lighting scheme design, implementation and operation.

14.4.4 Compensation methods

The initial higher lighting level necessary to compensate for the subsequent deterioration of the light output may be regulated in order to reduce energy consumption through the maintenance cycle—

(a) centralized electronic remote road lighting control systems enable luminaires to be dimmed to compensate for the initial overdesign of the lighting. The control system may dim the light level provided initially to that specified for compliance with the requirements of the lighting category and then progressively compensate for the deteriorating light output; and

(b) individual luminaires can incorporate integral control gear that automatically adjusts the lamp output to compensate for the deteriorating light output. Individual compensating control gear types include elctronic, magnetic and hybrid systems incorporating both magnetic and electronic technologies.

14.5 THE ASSET MANAGEMENT MAINTENANCE PROGRAM

14.5.1 Maintenance activities

The maintenance program adopted should include the following activities:

(a) Luminaire outage detection and service availability requirements.

(b) Lamp replacement and disposal.

(c) Luminaire cleaning and inspection.

(d) Tree management.

(e) Inspection, test, repair and replacement of equipment.

(f) Condition monitoring.

(g) Maintenance recording and performance review.

(h) Modification of maintenance program as required.

These activities are discussed in Clauses 14.5.2 to 14.5.9 and recommended performance levels given, where appropriate.

14.5.2 Outage detection and service availability requirements

Inspection patrols may be conducted at night as a visual check that luminaires are operating correctly.

Luminaire outage reports from the public are used to supplement patrol information. Public reports of luminaire outages in residential areas may be sufficient to obviate the need for patrols on minor roads. However, inspection patrols or other detection methods will be required for lighting installations on major roads (i.e. Category V lighting).

Frequencies of inspection patrols or other outage detection strategies and maintenance response times should be determined so that the maximum level of luminaire outages at any one time is not greater than 5% of the luminaire population. In other words, the service availability should be at least 95%. In addition, particular attention should be given to the rapid rectification of outages where two or more contiguous outages occur in any lighting scheme.

Priority should be given to the maintenance of lighting installations at higher risk areas including pedestrian crossings and major intersections.

14.5.3 Advanced central road lighting monitoring systems

Centralized electronic remote road lighting control systems enable lighting schemes to be monitored for outages that can be recorded centrally day-by-day. Advantages include the better management and quicker rectification of outages and better maintenance of the integrity of the lighting schemes.

14.5.4 Lamp replacement and disposal

Lamps should be replaced after failure or at a predetermined lamp change interval based on the burning hours at which the allowance for lamp lumen depreciation will be reached. The following strategies may be utilized:

(a) Replacement on failure of individual lamps (spot replacement).

(b) Selective replacement of individual lamps based on the date of installation, lamp type and allowable lamp lumen depreciation.

(c) Group or bulk change of all lamps in an area based on the average allowable lamp lumen depreciation for the lamp types so that a regular replacement interval is established.

(d) Combinations of the strategies outlined in Items (a) and (b) or (a) and (c) may be used.

Given the service availability requirements, as discussed in Clause 14.5.2, reported luminaire outages should be remedied by lamp replacement or repair or replacement of faulty equipment as soon as reasonably practicable, taking into account economic and operational considerations.

The recommended response time for such lamp replacements or other repairs is two to three days for major traffic routes, central business districts and pedestrian crossings.

NOTE: It is recognized that response times can be influenced by a number of factors. Factors that can lead to longer response times include road access restrictions, requirement for special equipment or materials, severe weather conditions and the aftermath of major structural or cable damage.

Selective lamp replacement programs require a comprehensive database incorporating records of lamp types, locations and dates of installations and subsequent dates of lamp changes. Cost advantages over bulk replacement may be realized by maximizing lamp life, particularly in the more costly higher wattage lamps, provided administrative and transport costs do not outweigh the savings.

Group or bulk lamp change programs may achieve economies of scale, through reduced transport costs and a regular lamp replacement program combined with other cyclic maintenance inspections. Traffic control arrangements tend to be more cost-effective than with selective replacement. Cost disadvantages will accrue from discarding lamps that have not reached the end of their useful life, either because of more recent spot replacement after failure or, because there is a variety of lamp types in the group, within the bulk change area and these lamp types have different average rates of lumen depreciation.

In determining the lamp change intervals for selective replacement or bulk change programs, the initial design levels of lamp lumen output are critical to the calculation of lamp life, given the manufacturer's lumen depreciation data. Initial design levels may be increased above the minimum levels to obtain a longer and more economic bulk change interval. Energy efficiency should be included as a consideration when evaluating this option. Other factors to also be considered in lamp change interval determination, include luminaire depreciation, Ingress Protection rating of the luminaire lamp chamber and luminaire cleaning, in conjunction with lamp changes.

Cost efficiencies may also be gained by undertaking associated maintenance activities on the road lighting installation in conjunction with bulk lamp change programs. The replacement of associated lighting equipment, including photoelectric switches, at relevant intervals, coinciding with multiples of the lamp change interval, should also be considered.

Disposal of lamps after they are removed from service should be undertaken in a safe and environmentally acceptable manner, having regard to any regulations or requirements of the appropriate authorities.

Breakage of lamps before disposal should be avoided because of the hazards of flying glass, exposure to toxic materials and in the case of low pressure sodium lamps, fire and a risk of explosion in confined, unventilated spaces.

14.5.5 Luminaire cleaning and inspection

The cleaning of luminaires is generally undertaken in conjunction with lamp replacement, for economic reasons and to restore the luminaires' reflecting, transmitting and refracting properties.

It is recommended that luminaire visors be wiped clean internally and externally with a clean, damp cloth washed out in water containing detergent. All reflecting surfaces should also be wiped clean with a clean, damp cloth. Visors should be replaced if cracked, opalised or substantially discoloured, or incomplete.

Luminaires fitted with photoelectric switches should also be cleaned around the PE switch housing to maintain switching efficiency.

A visual check of the luminaire for condition, deterioration or damage affecting its operation and performance should be undertaken. A visual check of all electrical components and wiring should also be carried out for signs of overheating. All accessible screws, nuts, and similar fasteners should be checked for tightness. The luminaire, access covers, visor and visor seal should be checked to ensure it is positioned correctly and fastened securely. If required, the luminaire should be re-aligned or re-adjusted to the design specification.

Where a luminaire becomes non operational and requires replacement and is of a type where a replacement luminaire is not readily available, i.e. some decorative luminaires, consideration should be given to fitting a temporary luminaire, if possible, to provide temporary lighting, pending the availability of the desired luminaire.

14.5.6 Vegetation management

The growth of vegetation in the vicinity of luminaires may significantly affect the performance of the road lighting installation and it is recommended that a vegetation-free zone be maintained in the vicinity of luminaires through a vegetation management program.

Alternatively, longer outreach arms or brackets, or closer luminaire spacings, may keep luminaires clear of vegetation, reduce the cost of tree trimming and maintain the required light technical parameters with minimal impact on the natural environment (see Clause 8.8).

14.5.7 Inspection, test, repair and replacement of equipment (other than lamps and luminaires)

The Asset Management maintenance program should include the inspection, testing, repair and monitoring of the condition of poles, brackets, switchboards and wiring systems forming part of the road lighting system, in accordance with regulatory requirements and sound Asset Management maintenance practices.

Inspection procedures should include the following:

(a) Brackets attached to wood or concrete poles should be inspected for corrosion or mechanical damage. Fixing bolts or bands should be checked to ensure the bracket is securely fixed to the pole.

(b) Steel and concrete poles should be visually inspected for corrosion and damage by impact or any malicious act and to ensure all accessible screws, nuts and access doors are secure.

In the case of frangible poles of the slip-base type, it is necessary to ensure the manufacturer's specified torques are maintained on the anchor cage holding down bolts and the slip base clamping bolts by retensioning. The ground level at the pole base should be maintained so the shear washer is at the required height above ground level for correct operation under vehicular collision.

The following additional maintenance actions should be undertaken, as practicable:

(i) Wood poles, cross arms and pole top fittings should be visually inspected for damage and degradation, or signs of termite infestation.

(ii) Switchboards, accessible wiring and electrical connections should be inspected to ensure there is no burning of contacts, no undue wear on moving parts and no damage to insulation exposing live parts. A check should also be made of the tightness of wiring connections and the continuity of MEN and direct earth connections.

(iii) Below-ground inspection and proof-testing of poles is generally carried out by specialist staff who use similar techniques to those employed in the maintenance inspection of electricity distribution poles. It is recommended the inspection procedures applicable to electricity distribution poles be followed for road lighting poles of the same type.

14.5.8 Condition monitoring

Condition monitoring is a maintenance technique that may be used on a statistical sample of the road lighting installation to modify maintenance cycle intervals, or to develop tests to replace regular inspection, or to establish replacement criteria for the whole installation, to achieve risk management and performance objectives.

Maintenance of supply voltage levels should not be overlooked in the life of the installation, as the circuit loading on the distribution network changes.

14.5.9 Maintenance records and performance review

It is essential that accurate records are kept of road lighting equipment including supply cabling.

This includes the locations, number and types of road lighting poles, lamps and luminaires, together with details of replacements, relocations and removals so the integrity of the road lighting design may be verified following maintenance work.

More comprehensive asset management record systems would enable the recording of luminaires reported as not working or damaged and include the reasons for luminaire outages and equipment failures. This will allow for more detailed analysis of the information to be undertaken and assist in the overall asset management of road lighting installations.

Recording of additional details of individual road lighting equipment, including manufacturer and manufacturing batch and the date and type of maintenance activity undertaken in a comprehensive asset management system will also assist in equipment performance monitoring and review processes, provide vital information on the service history of equipment, assist in the prioritization of the maintenance program, enable improvements in specification and selection of future lighting equipment and facilitate spares inventory management.

14.5.10 Modification of the maintenance program

As a result of monitoring, performance review, maintenance audit and feedback from maintenance crews and customers, it may be necessary to modify the maintenance program to reduce luminaire outage rates, improve outage response times and reduce operating costs by improving maintenance efficiency and productivity.

Where equipment performance monitoring identifies items that may assist in improved road lighting equipment reliability, performance, installabilty and maintainability, feedback should be provided to equipment manufacturers.

Improved performance may also be gained from the selection of more reliable, and cost-effective equipment and from the introduction of new technology in conjunction with effective Asset Management maintenance practices.

APPENDIX A

REFERENCED AND RELATED DOCUMENTS

(Normative)

A1 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS	
1348	Road and traffic engineering—Glossary of terms
1798	Lighting poles and bracket arms—Preferred dimensions
2979	Traffic signal mast arms
4282	Control of the obtrusive effects of outdoor lighting
60529	Degrees of protection provided by enclosures (IP Code)
AS/NZS	
1158	Lighting for roads and public spaces
1158.0	Part 0: Introduction
1158.1.1	Part 1.1: Vehicular traffic (Category V) lighting—Performance and design requirements
1158.2	Part 2: Computer procedures for the calculation of light technical parameters for Category V and Category P lighting
1158.4	Part 4: Lighting of pedestrian crossings
1158.6	Part 6: Luminaires
2648	Underground marking tape
2648.1	Part 1: Non-detectable tape
3000	Electrical installations (known as the Australian/New Zealand Wiring Rules)
CIE*Publication	
30.2	Calculation and measurement of luminance and illuminance in road lighting, 1975
47	Road lighting for wet conditions, 1979
AUSTROADS	
Guide to Road Design—Part 6:Road Design, Safety and Barriers	

A2 RELATED DOCUMENTS

Attention is drawn to the following related documents:

1 BARTON, E.V. and FREEMAN, K.D. (1988), *Frangible lighting poles: design, testing and use in Victoria*, Proceedings of 14th ARRB Conference, Vol. 14 No. 5, Australian Road Research Board.

2 BURRAGE, S. (1993), *Managing street lighting maintenance*, Lighting, Vol. 13, No. 3, pp.85-87.

3 CIE Publication No. 66 (1984), *Road surfaces and lighting*, International Commission on Illumination.

4 CIE Publication No. 93 (1992), *Road lighting as an accident countermeasure*, International Commission on Illumination.

5 CIE Publication No. 115 (2009), *Recommendations for the lighting of roads for motor traffic and pedestrian traffic*, International Commission on Illumination.

6 DE BOER, J.B. (ed) (1976), *Public lighting*, Phillips Technical Library, N.V. Phillips, Gloielampenfabrieken, Eindhoven, The Netherlands.

7 FGL Publication 3, *Good lighting for safety on roads*, paths and squares, Fordergemeinschaft Glutes Licht.

8 FISHER, A.J. (1968), *Visibility of objects against dark backgrounds with road lighting* Proceedings of 4th ARRB Conference, Australian Road Research Board.

9 FISHER, A.J. (1989), *Road lighting as an Accident Counter-Measure*, Proc. 35 IES ANZ National Convention Auckland 1989.

10 FOX, J.C., GOOD M.C. and JOUBERT, P.N., (1979) Report No. CRI *Collisions with utility poles*, Office of Road Safety, Australian Department of Transport.

11 HALL, R.R. (ed) (1980), *The design and implementation of fixed lighting for arterial roads and freeways*, Australian Road Research Board.

12 JACKETT, M.J. (1996), *Accident savings from road lighting in New Zealand*, Proceedings of Roads '96 Conference, Christchurch, New Zealand.

13 LAY, M.G. (1986), *Handbook on road technology*, Volume 2 Traffic Transport, Gordon and Breach.

14 NCHRP (1969), Report 77, *Development of design criteria for safer luminaire supports*, Highway Research Board.

15 OGDEN, K.W. and BENNETT, D.W. (eds) (1984), *Traffic engineering practice* (Third Edition), Department of Civil Engineering, Monash University.

16 PEARCE, R.A. and ARNDT, O.K. (1992), *Location of street lighting equipment at roundabouts*, Lighting in Australia. Vol. 12, No. 4, pp.114-118.

17 NAASRA, *Guide to traffic engineering practice* (1988), National Association of Australian State Road Authorities.

18 TRB Report 152 (1974), *Warrants for roadway lighting*, Transportation Research Board, U.S.A.

19 SCOTT, P.P. (1980), *The relationship between lighting quality and accident frequency*, TRRL Report 929, Transport and Road Research Laboratory, U.K.

20 TURNER, H. (1962), *The influence of road lighting on traffic safety and service*, Proc. ARRB Conf., 1 (1), p. 596.

21 TURNER, H. (1972), *The effectiveness of the New South Wales lighting subsidy scheme*, National Road Safety Symposium, Department of Transport, Canberra.

22 VAN BOMMEL, W.J.M. and DE BOER, J.B. (1980), *Road lighting*, Macmillan Press Ltd, London.

APPENDIX B

GUIDELINES FOR THE USE AND PLACEMENT OF RIGID AND FRANGIBLE ROAD LIGHTING POLES

(Informative)

B1 SCOPE

This Appendix provides guidelines for designers of road lighting on the selection and placement of road lighting poles in the road reserve. These guidelines have been formulated to cover the majority of situations that are encountered in road lighting design. Provided sound engineering judgement is used and appropriately documented, the guidelines may be varied to cater for atypical or unusual situations.

B2 APPLICATION

The guidelines set out in this Appendix apply to the following:

(a) New works.

(b) Reconstructed works.

(c) Situations where existing poles are to be replaced with an alternative type.

These guidelines do not apply to the following:

(i) Electricity distribution poles that are also used for road lighting by means of a bracket arm and luminaire affixed thereto.

(ii) Joint-use traffic signal and road lighting poles or combination traffic signal mast arm and road lighting poles. The locations of these are determined by the requirements of the traffic signal installation.

(iii) Installations existing prior to the issue of these guidelines.

The guidelines recognize two classes of road lighting pole type in terms of their performance with respect to vehicle impact: frangible and rigid. The term 'frangible road lighting pole' covers all types of road lighting poles specially designed to break away, yield or otherwise absorb the energy of an impacting vehicle, to the extent that the resultant deceleration forces on the vehicle and its occupants are reduced to within acceptable limits.

A number of frangible road lighting pole types exist. These differ in construction and the way they perform in a collision. Two types of frangible road lighting poles are commonly used: slip-base and energy (impact) absorbing. The characteristics of these two types of frangible road lighting poles are described in Paragraph B4.

The term 'rigid road lighting pole' covers all types of road lighting poles that do not meet the frangibility requirements for slip-base or energy absorbing types.

The recommendations of this Appendix relating to the positioning of road lighting poles represent the minimum that should apply for typical installations. These recommendations may need to be enhanced or increased where, by virtue of any combination of road surface, camber, change of direction or other road feature, it is considered that there may be a greater likelihood of errant vehicles than for straight sections of road.

B3 DEFINITIONS

For the purpose of this Appendix, the definitions given in AS/NZS 1158.0, AS 1348, AS 1798 and those below apply.

B3.1 High pedestrian activity areas

Areas typical of shopping centres, commercial areas, school areas, bus stops and multi-level dwellings.

B3.2 Other pedestrian activity areas

Areas with levels of pedestrian activity that do not qualify as high pedestrian activity areas in terms of Paragraph B3.1.

B3.3 Overhead line

An aerial conductor or conductors, together with associated supports, insulation and apparatus used for the transmission, distribution or conveyance of electricity.

B3.4 Rigid concrete median barrier

A substantial and specially shaped barrier separating opposing traffic streams and designed to deflect any errant vehicle parallel to the traffic stream, whilst minimizing damage to the vehicle, its occupants or the barrier.

B3.5 Speed limit

The maximum speed at which a motor vehicle is legally permitted to travel on a particular section of road.

B3.6 Pole setback zone

A range of pole setback distances, which are recommended for particular pole types (see Paragraph B5).

B3.7 85th percentile speed

The speed at or below which 85% of the vehicles travel.

B3.8 Clear zone

The area that begins at the edge of the travelled lane and is available for emergency use by errant vehicles that run off the road. This zone includes any adjoining lane/s, road shoulder, verge and batter. Refer to applicable road controlling authority for clear zone specifications.

Where the specifications for clear zone distances are not available refer to Austroads 'Guide to Road Design-Part 6: Road Design, Safety and Barriers' Table 4.1.

B4 POLE CHARACTERISTICS

B4.1 Rigid poles

Rigid poles are designed to withstand vehicular impacts without undue deformation whilst remaining in an upright position. This type of pole should not be used where there is a reasonable likelihood of impact from an errant vehicle.

B4.2 Frangible poles

B4.2.1 *Pole types*

There are two types of frangible poles recognized by these guidelines, namely—

(a) slip-base (see Paragraph B4.2.2); and

(b) energy-absorbing (see Paragraph B4.2.3).

Typical collapse modes for these pole types are illustrated in Figure B1. Due to the collapse modes of frangible poles, particular care needs to be taken in their placement near power lines and in built up areas. The applicable road controlling authority documents should be consulted for the appropriate clearances.

B4.2.2 *Slip-base poles*

Slip-base poles are a very effective form of frangible pole, having been rigorously tested and developed, both overseas and in Australia, over many years. Slip-base poles have been widely used on freeways and other high speed roads in many countries and are now becoming more widely used on normal road and street situations where there is sufficient clearance to overhead power lines and the likelihood of secondary crashes arising from the dislodged pole is acceptably small.

A characteristic of slip-base poles is that, when impacted at normal urban operating speeds, they are generally dislodged from their original position and often do not significantly retard the progress of the impacting vehicle. This gives rise to concern about secondary crash potential where this type of pole is used in areas of high pedestrian activity, parking and abutting development density and in narrow medians. It is strongly recommended that slip-base poles not be used in high pedestrian activity areas.

In-service experience with frangible poles of the slip-base type, both in Australia and overseas, shows that, when these poles are impacted by an errant vehicle, they generally fall within the path travelled by the vehicle.

To ensure that a slip-base pole behaves in the designed manner, it is important that the pole be installed correctly. Reference should be made to the applicable road controlling authorities policies and practices regarding the installation of these poles.

B4.2.3 *Energy-absorbing poles*

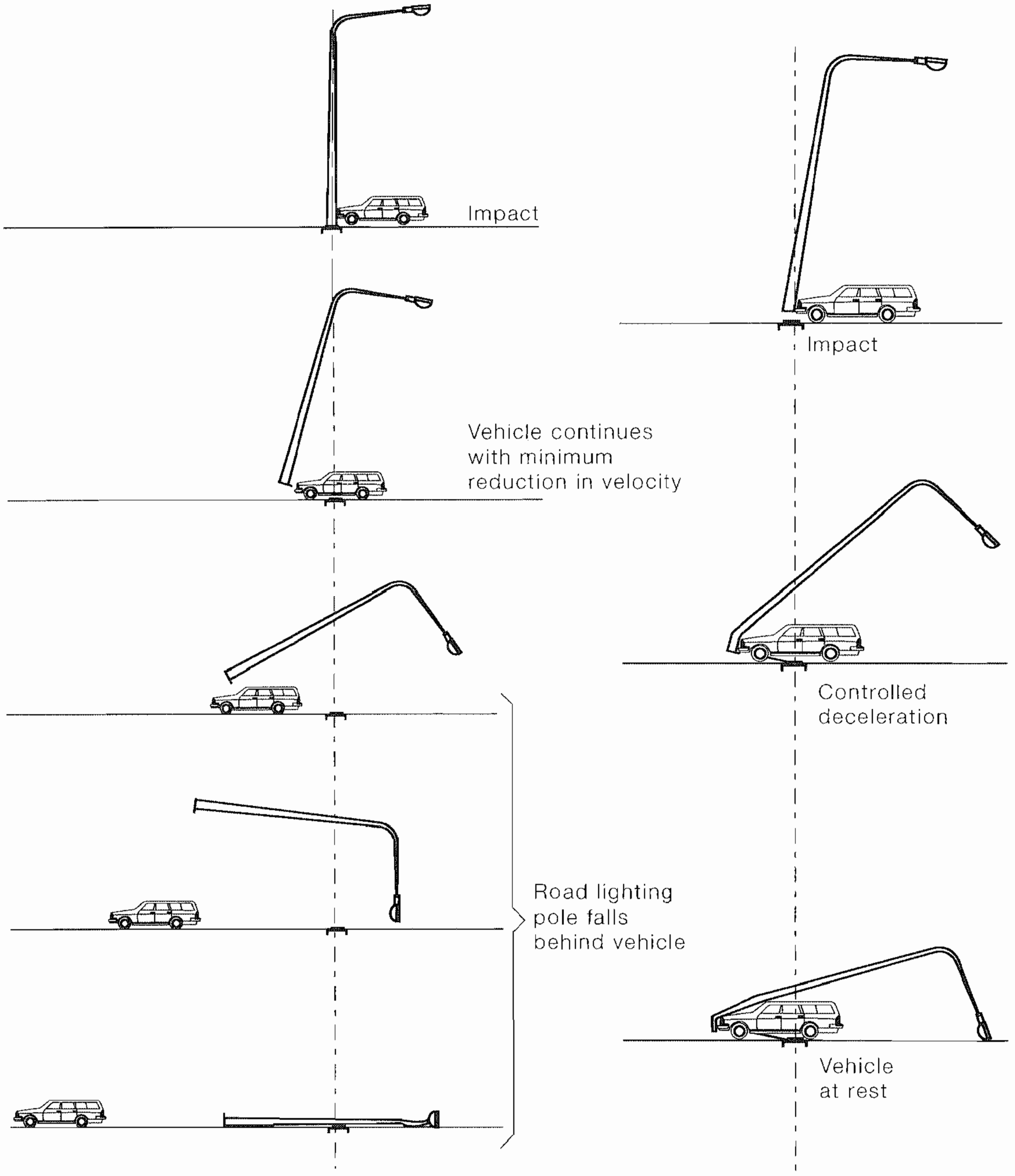
Energy-absorbing poles are very similar in outward appearance to the normal rigid pole. They differ from frangible poles of the slip-base type in that, in a vehicle impact, they remain attached to the base structure and absorb any impact energy by progressively deforming and entrapping the impacting vehicle. The deformation of the pole is controlled by a 'designed' weakening of the pole stem over the lower length.

B5 POLE SELECTION

Acceptable locations for lighting poles are identified in Table B1, in combination with Figures B2 and B3, based on the pole type, pole setback zone and the level of pedestrian activity in the area where the pole is installed. Table B1, with Figures B2 and B3, also identifies locations where poles–

(a) are not recommended; or

(b) should be totally excluded.


Impact
Vehicle continues with minimum reduction in velocity
Road lighting pole falls behind vehicle
Impact
Controlled deceleration
Vehicle at rest

(a) Slip-base poles

(b) Impact-absorbing poles

FIGURE B1 COLLAPSE MODES FOR FRANGIBLE POLES

TABLE B1
GUIDE TO POLE SELECTION

1	2	3	4	5	6
Pedestrian activity	**Pole type**		**Pole setback zone (see Figure B2)**		
			1	**2**	**3**
High	Rigid		E	N	A
	Frangible	Energy-absorbing	E	A	A
		Slip-base	E	N	N
Other areas	Rigid		E	N	A
	Frangible	Energy-absorbing	E	A	A
		Slip-base	E	A	A

LEGEND:
A = Acceptable
N = Not recommended
E = Total exclusion

NOTES:

1 Recommendations concerning the use of frangible poles only apply where the location will allow the pole to deform, as designed, on vehicular impact (see Paragraph B6.9). It is not recommended that frangible poles be installed through awnings or adjacent to structures or ground features that could alter their energy-absorbing characteristics.

2 In locations where frangible poles cannot be used, it is recommended that use of a rigid pole protected by guard fencing be considered. Note, however, that incorrectly installed guard fence could constitute a greater hazard than the lighting pole (see Paragraph B6.8). If there is any doubt about the type of guard fence that should be used, the applicable road controlling authority should be consulted.

B6 POLE SETBACK ZONES

B6.1 General

Three pole setback zones are referred to in this Appendix. They comprise an area of the road shoulders or verges, parallel to the roadway, and can generally be described as follows:

(a) *Zone 1 (pole total exclusion zone)* This zone lies closest to the outer edge of the traffic lane(s). It extends to a distance, perpendicular to the road alignment, as follows:

    (i) For *kerbed road*—normally 0.7 m beyond the kerb but extending to 1.0 m at intersections.

    (ii) For *unkerbed road*—not less than 1.0 m beyond the edge of the carriageway.

(b) *Zone 2 (frangible pole zone)* This is the area that lies between Zones 1 and 3 and includes the clear zone, which is free of hazards and specified by the applicable road controlling authorities documents. Any type of frangible pole is acceptable for use in this zone except that slip-base poles should not be used in areas of high pedestrian activity. The use of rigid poles in this zone is not recommended.

(c) *Zone 3 (unrestricted pole usage zone)* This zone is furthermost from the edge of the traffic lane and is outside the clear zone. Any type of pole is acceptable in this zone except that slip-base poles should not be used in high pedestrian activity areas.

The dimension of interface between zones 2 and 3 is equal to the clear zone dimensions documented in the applicable road controlling authority guidelines on safety barriers and road side furniture or as defined in Austroads Guide to Road Design, Part 6, Table 4.1. There should be no fixed base (or non-frangible) poles within the clear zone. For the purpose of this Appendix, pole setback zones are set out in Figure B2

The recommended pole setback zones are subject to local regulations and site limitations, including nominated pole alignments and electricity authority requirements for clearance to overhead power lines. If a reduction in Zone 1 is necessary, careful consideration should be given to vehicle overhangs and the road camber to minimize possible damage to poles and vehicles.

NOTE: The traffic speed for the placement of poles is normally the posted speed limit. However, consideration should be given to the 85th percentile speed of the road, if it is significantly higher than the posted speed limit.

B6.2 Straight sections

B6.2.1 *General*

The provisions of Paragraphs B5 and B6.1 apply for straight sections of road except for steep cut/fill embankments where the verge is not readily traversable, as described in Paragraph B6.2.2.

B6.2.2 *Steep cut/fill slope embankments*

B6.2.2.1 *General*

Applicable road controlling authority documents should be consulted to determine whether the embankment is considered more of a hazard then the pole.

Recommendations for pole types and locations for cut/fill embankments are set out in Paragraphs B6.2.2.2 and B6.2.2.3 respectively.

It is recommended that slip-base and energy-absorbing poles not be positioned on cut/fill slopes steeper than 3:1 as the impact characteristics of these types of poles cannot be guaranteed for such slopes.

B6.2.2.2 *Cut slope embankments*

For cut slope embankments, it is recommended that fixed base poles be used and that they be located on the flat at the top of the slope or, in any case, as far from the edge of the traffic lane as erection and access requirements will permit. Applicable road controlling authority documents should be consulted to establish if the pole needs to be protected with a barrier.

B6.2.2.3 *Fill slope embankments*

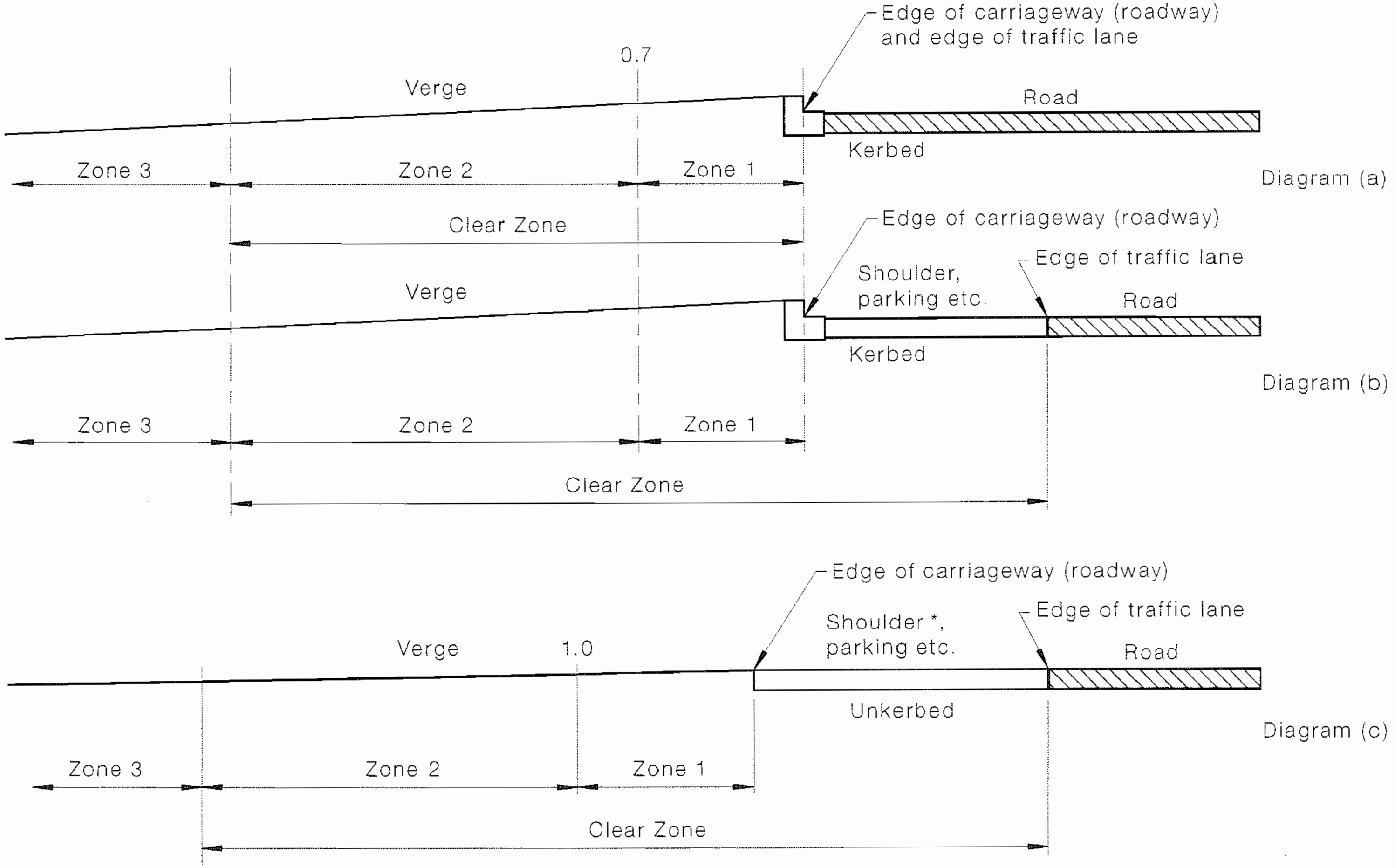
Care should be taken in selecting the location and type of pole for fill slope embankments due to the likelihood of uncontrolled run-off of errant vehicles. It is recommended that the pole be located at the bottom of the fill slope embankment or, in any case, as far from the edge of the traffic lane as erection and access requirements will permit. If slip base poles are used on fill slopes, care should be taken to prevent the errant vehicle snagging on the foundation section of the slip base. Care should also be taken to ensure the errant vehicle cannot impact the slip base pole too high above the slip base plane. Manufacturers of the poles should be consulted to establish the appropriate range of vehicle impact points.

B6.3 Curves and bends

The placement of poles on the outside of curves should follow the clear zone requirements as published in the applicable road controlling authorities documents. Slip base and energy absorbing poles can be located within the clear zone. The use of fixed base poles is not recommended to be located in the clear zone. All poles should be excluded from Zone 1.

B6.4 Verges at intersections

The provisions of Paragraph B5 apply provided that Zone 1 in Figure B2 is increased in width from 0.7 m to 1.0 m in the vicinity of corners to allow for the possibility of long vehicles riding up over the kerb whilst turning. For the purpose of applying this recommendation, the increased Zone 1 width should extend 5 m beyond the tangent points (TP) as illustrated in Figures B3 and B4.



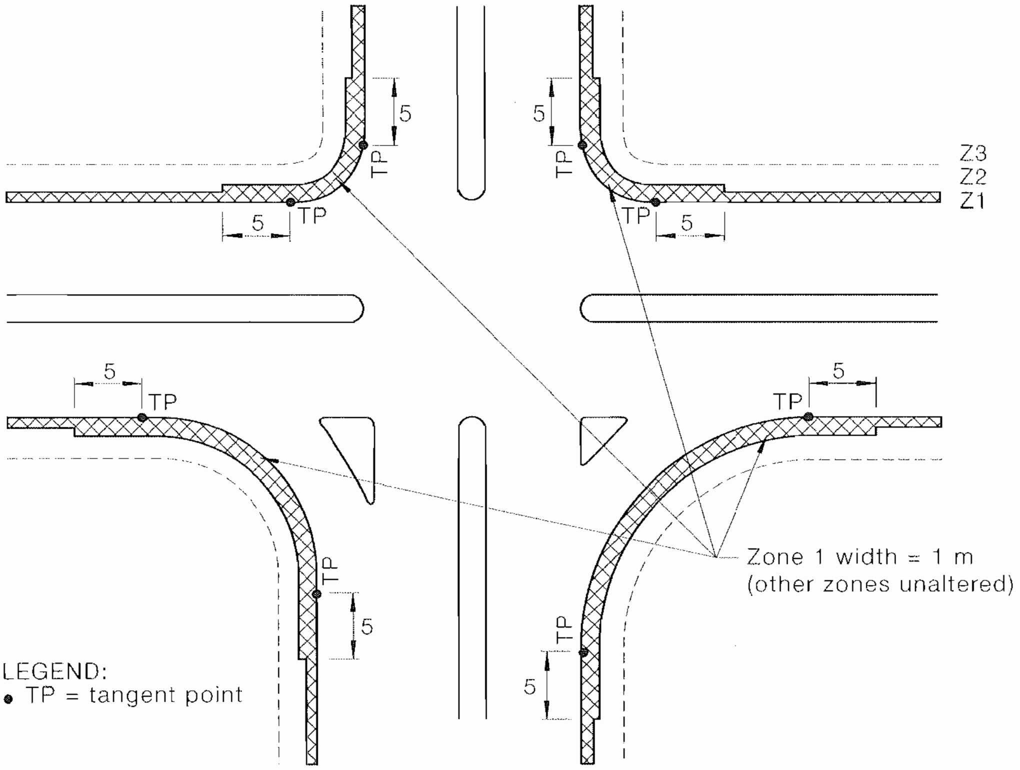
* - For the purposes of pole setback zones the shoulder may be sealed or unsealed.

The dimensions shown are minimum requirements. Poles should be setback as far from the edge of carriageway as site conditions and equipment specification allow.

NOTE: See Paragraph B6.1 for a general description of the three setback zones and their application with respect to the siting of road lighting poles

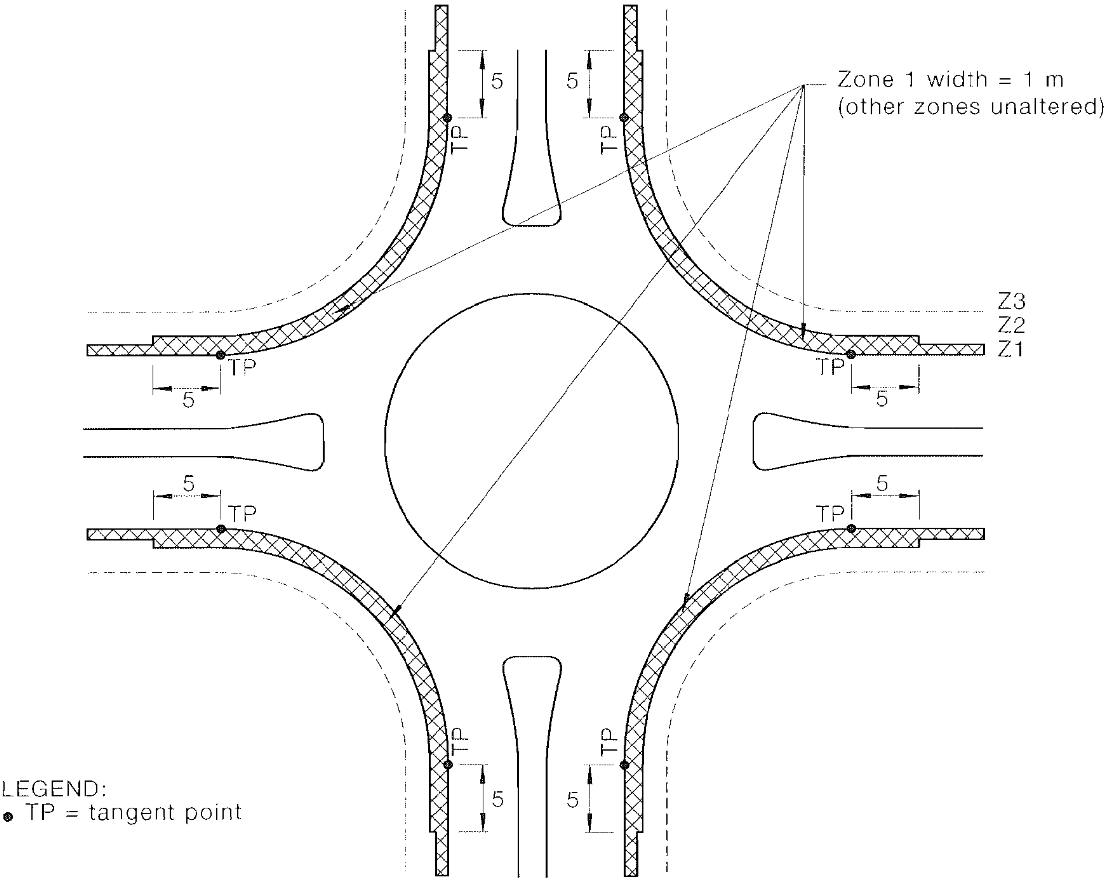
DIMENSIONS IN METRES

FIGURE B2 ROAD LIGHTING POLE SETBACK ZONES



DIMENSIONS IN METRES

FIGURE B3 ZONE 1 POLE SETBACK AT INTERSECTIONS WITH TYPICAL VERGES



DIMENSIONS IN METRES

FIGURE B4 ZONE 1 POLE SETBACK AT ROUNDABOUTS WITH TYPICAL VERGES

B6.5 Islands, medians, splitters and separators

The provisions of Paragraphs B5 and B6.1 apply with the following additional recommendations and qualifications.

(a) Poles should not be positioned in gore areas.

(b) The pole setback distance from noses should generally be 6 m but this may need to be reassessed depending on the road geometry and speed of traffic flow.

(c) It is recommended that poles positioned in the central median be of the frangible type and, wherever practicable, be located along the centre-line of the median. Care should be taken when positioning poles in depressed medians to ensure errant vehicles are not channelled along the depression into a pole. Where possible 'V' drains should be offset from the centre line of the depressed median.

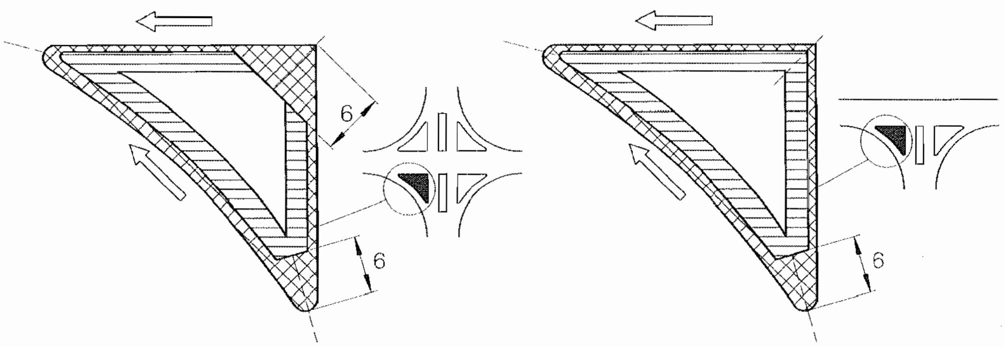
(d) It is recommended that poles not be located in splitter islands or in central medians less than 2 m wide.

Diagrams illustrating pole setback zones for islands, medians, splitters and separators are given in Figure B5.

B6.6 Roundabout central islands

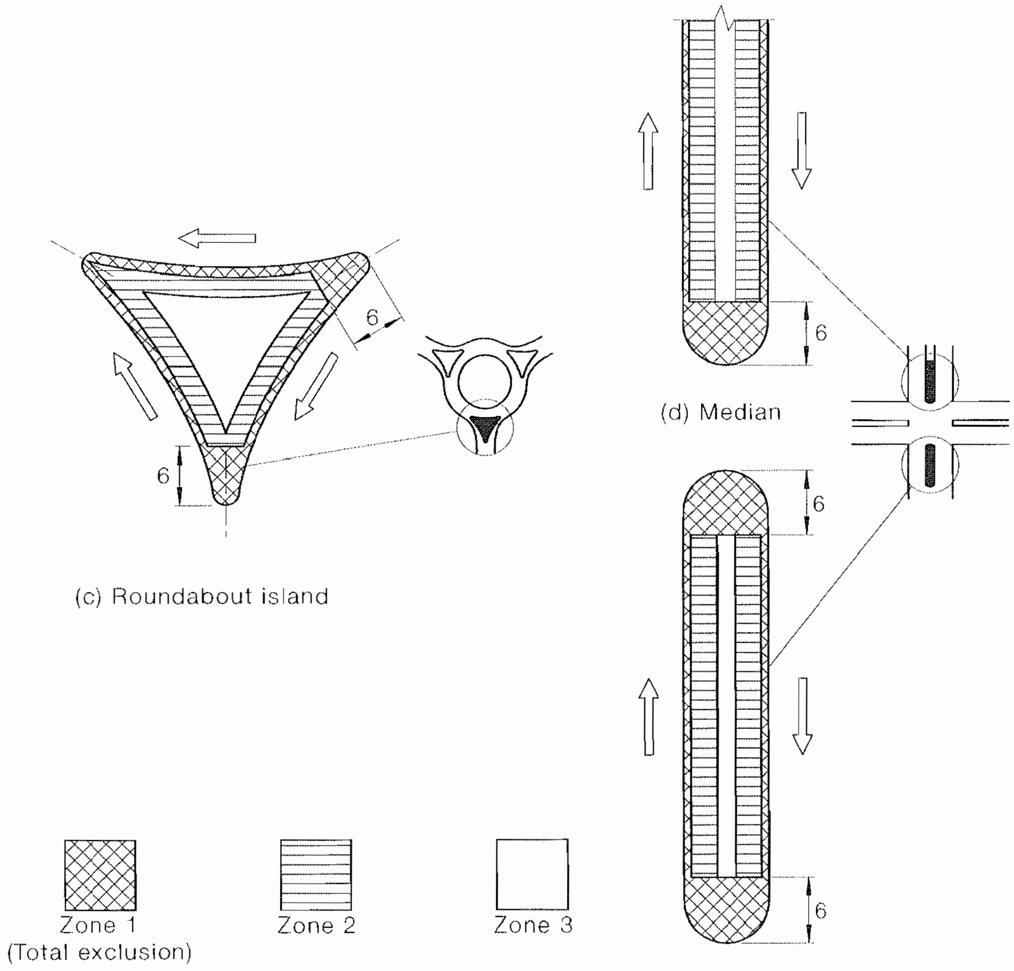
The provisions of Paragraphs B5 and B6.1 apply with the exception that it is recommended poles not be installed in roundabout central islands of diameter less than 6 m. Access for maintenance vehicles needs to be determined in consultation with the applicable road controlling authority.

Pole setback zones for roundabout central islands are illustrated in Figure B6.



(a) Left turn island at intersection

(b) Left turn island at junction



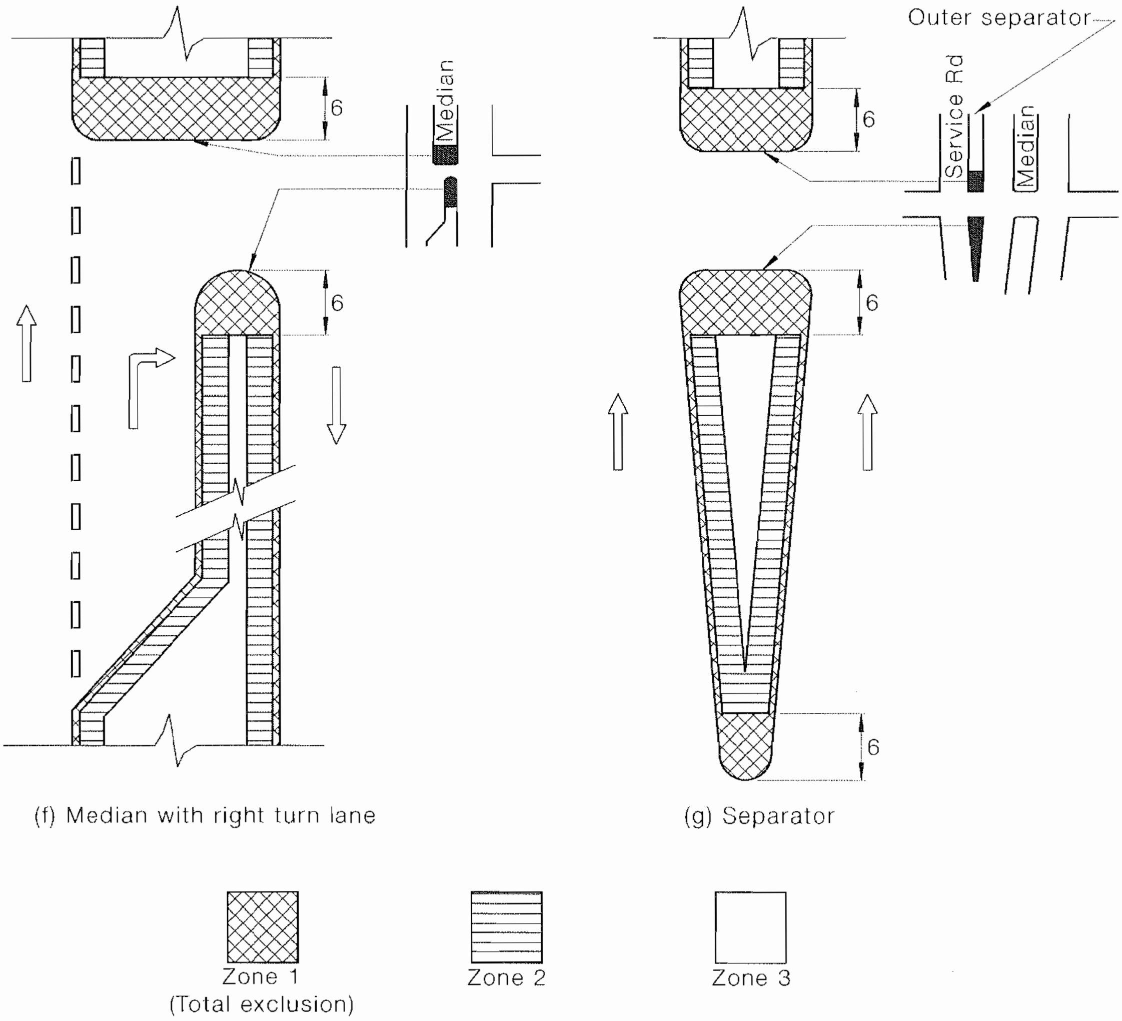
(c) Roundabout island

(d) Median

(e) Splinter

DIMENSIONS IN METRES

FIGURE B5 (in part) POLE SETBACK ZONES FOR ISLANDS, MEDIANS, SPLITTERS AND SEPARATORS



(f) Median with right turn lane

(g) Separator

DIMENSIONS IN METRES

FIGURE B5 (in part) POLE SETBACK ZONES FOR ISLANDS, MEDIANS, SPLITTERS AND SEPARATORS

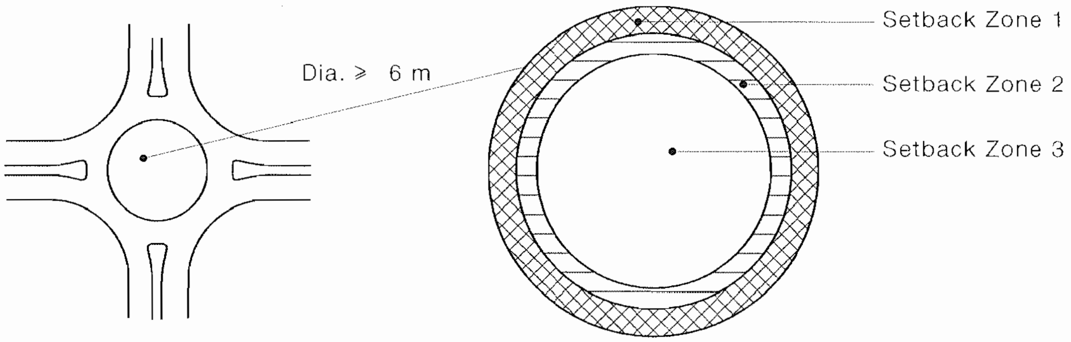


FIGURE B6 POLE SETBACK ZONES FOR ROUNDABOUT CENTRAL ISLANDS

B6.7 Concrete median barrier

The provisions of Paragraphs B5 and B6.1 do not apply where the pole forms an integral part of a rigid concrete median barrier. In this situation, it is recommended that the pole be of the rigid type. Poles used in conjunction with median barriers will generally need to have inspection hatchways higher than normal to allow unobstructed access to the pole interior.

B6.8 Semi-rigid and flexible barriers (guard fence and wire rope)

The recommendations of Paragraphs B5 and B6.1 do not apply where the pole is protected by a semi-rigid or flexible barrier. These types of barriers are designed to deform under impact. Therefore, it is important that poles not be positioned within the deflection zone, measured from the face of the barrier. The extent of the deflection depends upon the posted speed limit, the type of barrier and the angle factor. Where a semi-rigid or flexible barrier is present (see Figure B7), it is recommended that poles be of the fixed-base type and installed outside the deflection zone of the barrier. Poles should also be located outside the runout length of the barrier. The applicable road controlling authority guidelines should be consulted to confirm the pole setback requirements.

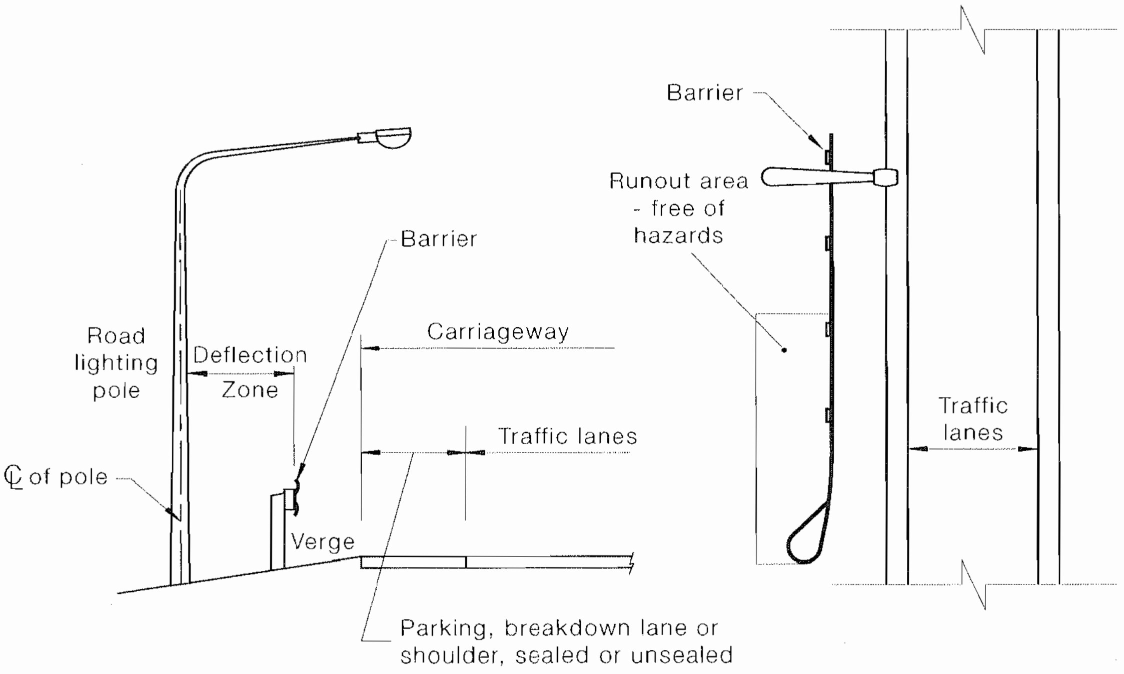


FIGURE B7 LOCATION OF POLE BEHIND SEMI-RIGID OR FLEXIBLE BARRIER

B6.9 Non-traversable permanent obstructions

B6.9.1 *General*

The provisions of Paragraphs B5 and B6.1 do not apply where a non-traversable permanent obstruction exists adjacent to a proposed pole site.

B6.9.2 *Obstruction in front*

Where the non-traversable permanent obstruction is in front of a proposed pole position, then a rigid pole may be placed behind the obstruction as near as erection and access requirements will permit (see Figure B8).

B6.9.3 *Obstruction behind*

Where the non-traversable permanent obstruction is behind the proposed pole position and it is considered that the obstruction would affect the operation of a frangible pole, then it is acceptable to use a rigid pole giving due consideration to erection and access requirements (see Figure B9).

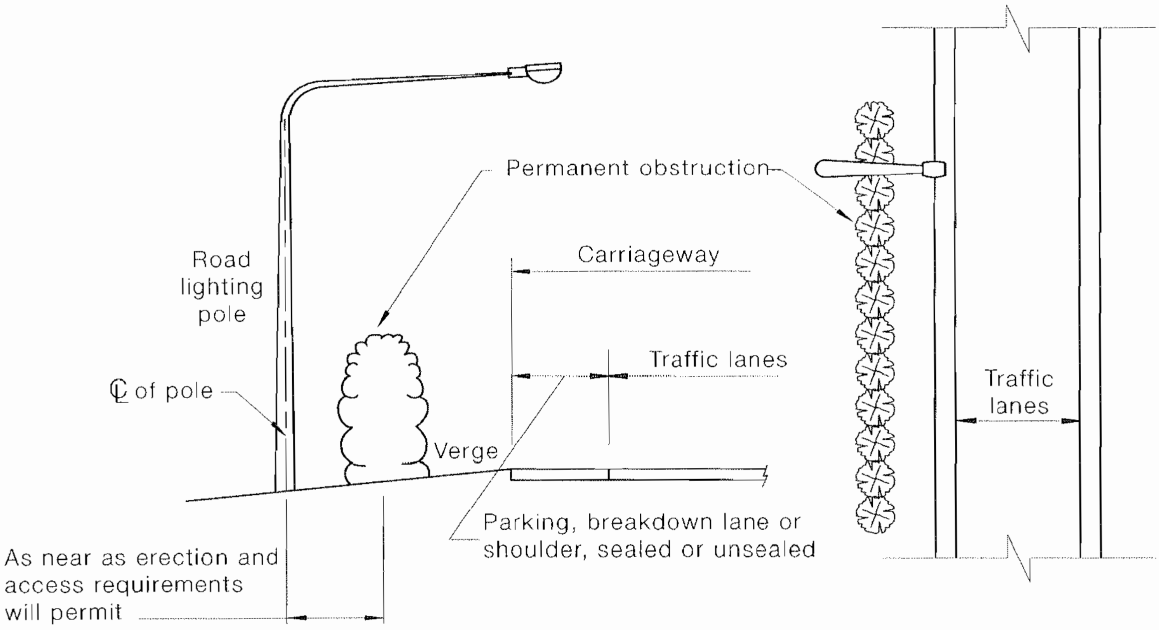

Permanent obstruction
Carriageway
Road lighting pole
Traffic lanes
℄ of pole
Traffic lanes
Verge
Parking, breakdown lane or shoulder, sealed or unsealed
As near as erection and access requirements will permit

FIGURE B8 NON-TRAVERSABLE PERMANENT OBSTRUCTION IN FRONT OF POLE

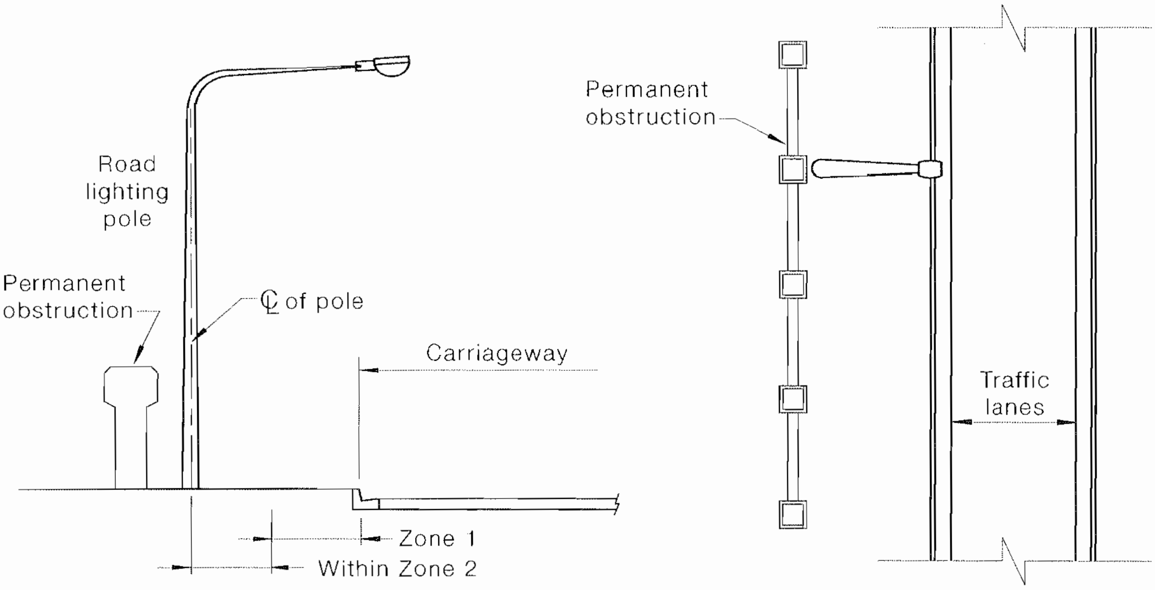


FIGURE B9 NON-TRAVERSABLE PERMANENT OBSTRUCTION BEHIND POLE

APPENDIX C

THE PROBLEM OF NIGHT ROAD CRASHES AND ROAD LIGHTING AS A CRASH COUNTERMEASURE

(Informative)

C1 INTRODUCTION

This Appendix sets out a statement on the night crash situation and on road lighting as a proven, economically viable crash countermeasure. The details given are taken from Ref. 9 in Paragraph A2.

C2 ROAD CRASHES AT NIGHT

Road crashes occurring at night are disproportionately higher in numbers and severity compared to daytime. The proportion of fatal crashes at night in 13 OECD countries ranges between 25% and 59%, average value 48.5%. Estimates of vehicle kilometres travelled during the hours of darkness range from 17% to 32%, average value 25%.

C3 REASONS FOR HIGHER NIGHT CRASH RATE

Individually, factors such as increased alcohol usage, fatigue, and over representation of young drivers in night traffic contribute to the problem. However, the major factor is darkness, as is demonstrated in crash studies in which the effect of these other factors has been taken into account.

At night, with low light levels, man's visual capabilities, such as acuity, distance judgement, speed of seeing, colour discrimination and glare tolerance are impaired. There are also adverse interactions between impaired vision and other factors, such as inclement weather.

As a result, visibility is severely reduced at night. Thus, it would be expected that the provision of light through road lighting would be a countermeasure.

C4 ROAD LIGHTING—A SUCCESSFUL CRASH COUNTERMEASURE

Sixty two lighting and crash studies from 15 countries have been evaluated. Some 95% of results show lighting to be beneficial, with about one third of these having statistical significance. Therefore, the overwhelming evidence is that road lighting is successful.

However, the installation of lighting cannot be expected to result in a reduction in crashes if there is a major non-visual problem at any particular site.

The numerical values of the benefits are summarized in Table C1. For each road class, the first line gives the details of results that have statistical significance and the second line gives details of all results whether significant or not. The results are given only from before and after studies involving the implementation or upgrading of lighting on traffic routes.

Results from studies surveying roads with and without lighting, or those concerned with economies of lighting through reducing or switching out have been excluded, being less robust than the before and after type of study.

Table C1 shows the average reduction in crashes is at least 30%, since this value is exceeded in each cell for which there are statistically significant results. This conclusion is supported by the non-significant results and also by the survey and lighting economy studies not included in the Table.

This value can be used for benefit/cost analysis, feasibility studies and the like, if a single composite value for crash reduction is required. However, if a result of a local study is available, it should be used, or alternatively a figure within the range given in Table C1 can be selected for a particular application.

TABLE C1

SUMMARY OF THE BENEFITS OF LIGHTING (PERCENT REDUCTION OF NIGHT-TIME CRASHES)*

1	2	3	4	5	6	7	8	9	10
Road class	**Crash classification**								
	All crashes			**Pedestrian**			**Casualty**		
	Sample	**Range**	**Mean**	**Sample**	**Range**	**Mean**	**Sample**	**Range**	**Mean**
1. Urban									
(a) Continuous	3 10	21 to 75 9 to 75	43 29	2 4	46 to 75 16 to 57	51 42	6 9	29 to 48 16 to 48	34 29
(b) Pedestrian crossing				1 8	 32 to 74	64 54			
2. Rural									
(a) Continuous	2 4	13 to 75 13 to 75	44 37				2 6	38 to 53 13 to 100	45 44
(b) Junction	1 2	 26 to 44	44 35				0 1		 9
3. Freeways									
(a) Continuous	2 4	13 to 75 13 to 75	44 37				2 6	38 to 53 13 to 100	45 44
(b) Interchanges	1 2	 26 to 44	44 35				0 1		 9

* See Paragraph C4 for further information on the crash data quoted

C5 THE INFLUENCE OF THE QUALITY OF THE LIGHTING

In most studies, the lighting was upgraded from poor or no lighting to good lighting. Good lighting is often defined as at least equal to that of the national lighting standard at the time. Little can be said definitely about the relationship between crash reduction and individual light technical parameters describing lighting quality.

Crashes decrease as the light provided in an installation increases. However, there is a law of diminishing return and the level of lighting at which there is no further decrease in crashes may be several times higher than is usual in national standards.

As a corollary, with reasonable supporting evidence from lighting economy studies, the reduction or switching out of lighting has an adverse effect on safety.

Another measure of quality is uniformity of luminance. There is some evidence that, if uniformity is too great, the safety benefit associated with a particular light level may be reduced. (This may be attributed to the lack of references in very uniform surrounds by which motorists judge speed and headways—'the visual desert' syndrome).

There is no information available on the influence of other quality criteria, such as glare, on accident reduction.

C6 COSTS AND BENEFITS OF ROAD LIGHTING

Road lighting can be expected to reduce crashes. However, to be cost effective, the crash savings in monetary terms have to be greater than the capital and running costs of the lighting, taken over the life of the installation.

Lighting on arterial roads, particularly in urban areas, will more than pay for itself in crash savings. This is without considering other benefits, such as reduction of distress caused by death and injury, and possible increased traffic service and efficiency, crime prevention possibilities and improved amenity. However, in the cost benefit evaluation, it is important to consider possible crash hazards resulting from the installation of the lighting poles. These can be minimized by setback, guardrail or use of frangible, energy-absorbing or slip-base poles.

It appears that lighting is justified on urban arterial roads (non-freeway) if the night casualty rate exceeds about one per kilometre per year or if the annual daily traffic exceeds about 10 000 vehicles. For freeways and motorways these warrants will be somewhat higher. Exact warrants can be derived from the cost structure pertaining to a particular country and location.

The sensitivity of the conclusions of cost/benefit calculations to the accuracy of the input values should be tested by varying all items, including the crash reduction value chosen by the methods given in Paragraph C4.

C7 CONCLUSION

A general conclusion, for the purpose of evaluating road lighting as a crash countermeasure and preparing engineering warrants, is that the provision of road lighting may reduce night crashes when properly designed, installed and maintained. The most reliable studies show reductions to be between 13% and 75%, depending on the class of traffic route and the crash classification involved.

APPENDIX D

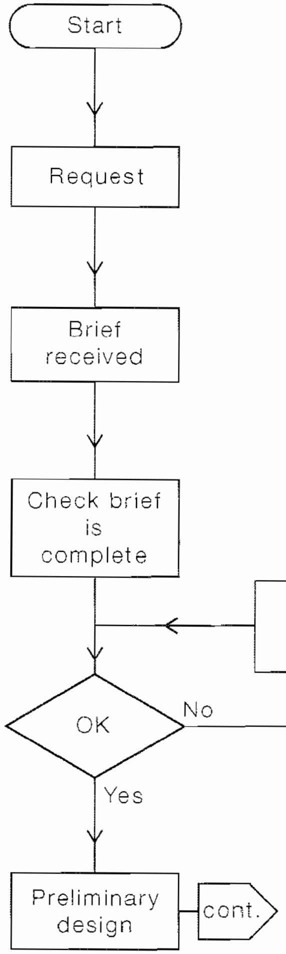
TYPICAL FULL ROAD LIGHTING DESIGN PROCESS

(Informative)

Figure D1 illustrates the steps normally involved in the process of carrying out a full road lighting design. Not all of the steps illustrated will necessarily be required in the design of a particular installation.

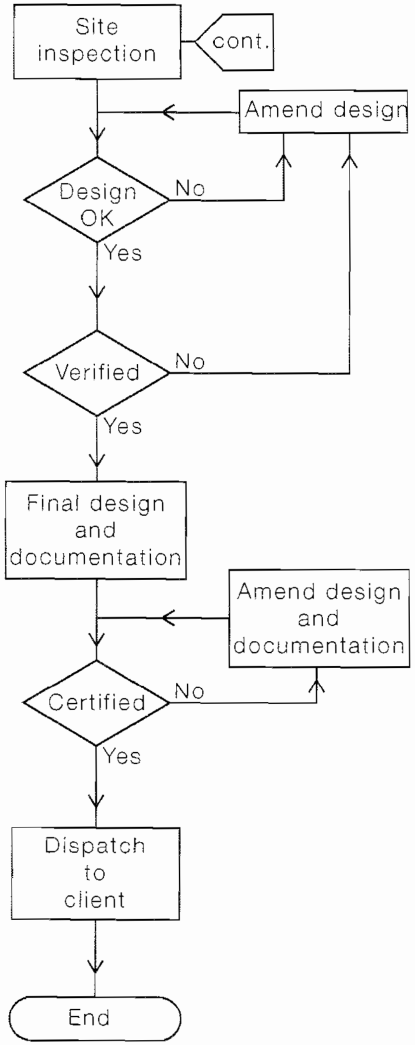
Figure D1 makes reference to Figures D2 and D3 for details of the preliminary and final design processes respectively.

FLOW CHART



COMMENTS	AUDIT DETAILS		Initials	Date
- Start of road lighting design process.				
- Client requests a road lighting design.	Yes ☐	No ☐	☐	__/__/__
- A brief is prepared by the client and should contain all relevant design and site information. The designer may need to work with the client in the preparation of the initial brief.	Yes ☐	No ☐	☐	__/__/__
- See Clause 6.3.2.	Yes ☐	No ☐	☐	__/__/__
- Before proceeding, the brief should be finalised with the client. The final brief content is the responsibility of the client.	Yes ☐	No ☐	☐	__/__/__
- Design brief is complete.	Yes ☐	No ☐	☐	__/__/__
- See separate details in Figure D2.	Yes ☐	No ☐	☐	__/__/__

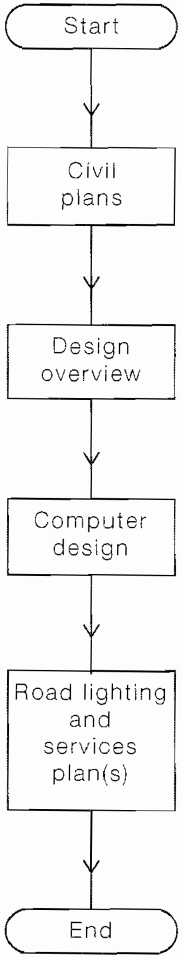
FIGURE D1 (in part) TYPICAL FULL ROAD LIGHTING DESIGN PROCESS



			Initials	Date
● A site inspection should be performed. See Clause 6.3.3.	Yes ☐	No ☐	☐	__/__/__
● Revise the preliminary design to include relevant information as identified during the site inspection.	Yes ☐	No ☐	☐	__/__/__
● Preliminary design is OK.	Yes ☐	No ☐	☐	__/__/__
● Preliminary design is verified for its compliance with the design brief.	Yes ☐	No ☐	☐	__/__/__
● See separate details in Figure D3.	Yes ☐	No ☐	☐	__/__/__
● Amend final design and documentation as appropriate.	Yes ☐	No ☐	☐	__/__/__
● Final design and documentation is certified for its compilance with the design brief.	Yes ☐	No ☐	☐	__/__/__
● Dispatch the certified road lighting design to the client.	Yes ☐	No ☐	☐	__/__/__
● End of road lighting design process.				

FIGURE D1 (in part) TYPICAL FULL ROAD LIGHTING DESIGN PROCESS

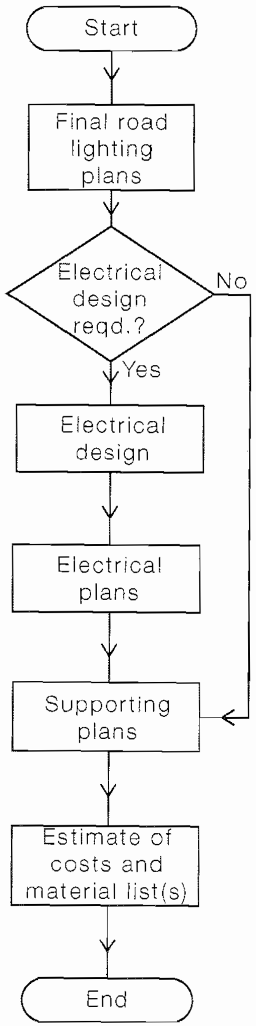
FLOW CHART



COMMENTS	AUDIT DETAILS			
			Initials	Date
● Start of preliminary road lighting design process.				
● Produce the basic civil (road) layout plan(s) on which the road lighting design will be displayed.	Yes ☐	No ☐	☐	__/__/__
● Develop a design overview using performance/spacing tables, giving due consideration to policy considerations. See Sections 4 and 9.	Yes ☐	No ☐	☐	__/__/__
● Optimize design using SAA STAN or illuminance-based computer program(s), as applicable. See AS/NZS 1158.2	Yes ☐	No ☐	☐	__/__/__
● Produce preliminary road lighting and services plan(s) giving due attention to recommended lighting layouts. See Clause 10.3	Yes ☐	No ☐	☐	__/__/__
● End of preliminary road lighting design process.	Yes ☐	No ☐	☐	__/__/__

FIGURE D2 PRELIMINARY ROAD LIGHTING SESSION

FLOW CHART



COMMENTS	AUDIT DETAILS		Initials	Date
● Start of final road lighting design process.				
● Prepare final road lighting design plans as follows: (a) Road lighting locality key plan(s). (b) Road lighting and services plan(s). (c) Road lighting schedule plan(s).	Yes ☐	No ☐	☐	__/__/__
● Electrical design required?	Yes ☐	No ☐	☐	__/__/__
● See Clause 10.4	Yes ☐	No ☐	☐	__/__/__
● Prepare electrical plans as follows: (a) Road lighting schematic(s) - line diagram(s). (b) Road lighting circuit schedule plan(s). (c) Switchboard plan(s).	Yes ☐	No ☐	☐	__/__/__
● Prepare supporting plans as follows: (a) Pit allocation plan(s). (b) Work plan(s). (c) Standard/special plan(s).	Yes ☐	No ☐	☐	__/__/__
● Prepare estimate of costs and material lists.	Yes ☐	No ☐	☐	__/__/__
● End final road lighting design process.				

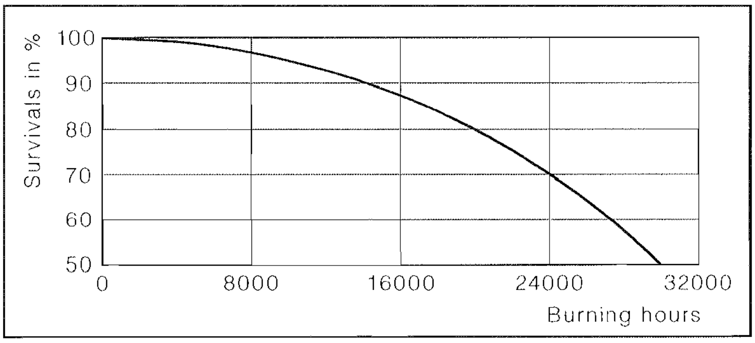
FIGURE D3 FINAL ROAD LIGHTING DESIGN

APPENDIX E

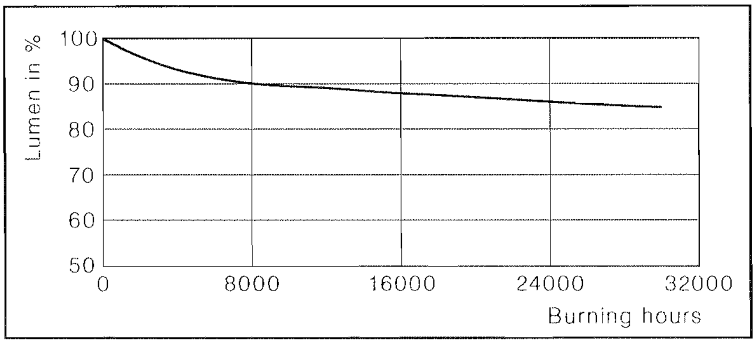
TYPICAL PERFORMANCE CURVES SHOWING LAMP MORTALITY AND LUMEN DEPRECIATION

(Informative)

Figures E1 to E4 below are typical performance curves illustrating mortality and lumen depreciation data for lamp types applicable to Category V lighting. The data given is generally representative of lamps from different manufacturers but should not be used for design purposes. (See Table 5.1.)

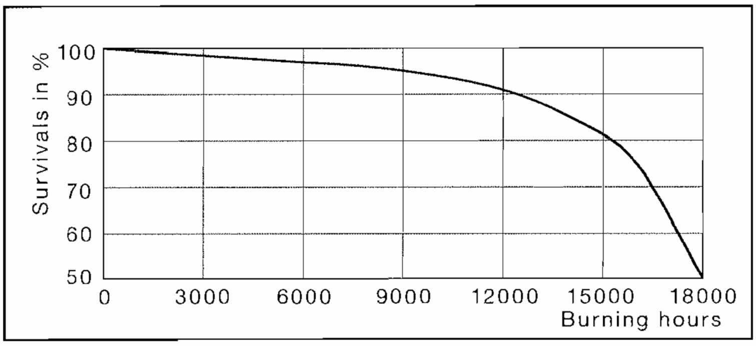


Lamp mortality

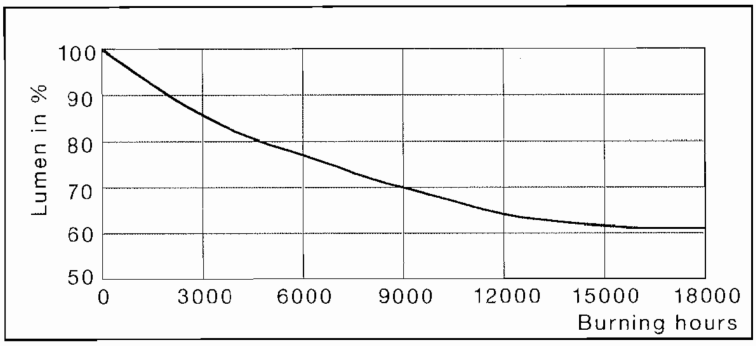


Lumen depreciation

FIGURE E1 TYPICAL LAMP MORTALITY/LUMEN DEPRECIATION DATA FOR HIGH PRESSURE SODIUM VAPOUR LAMP

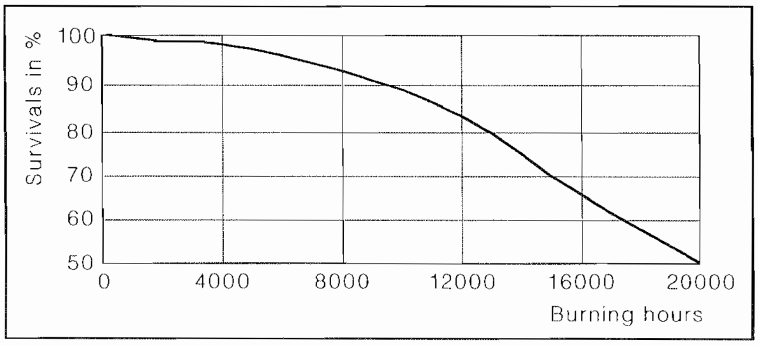


Lamp mortality

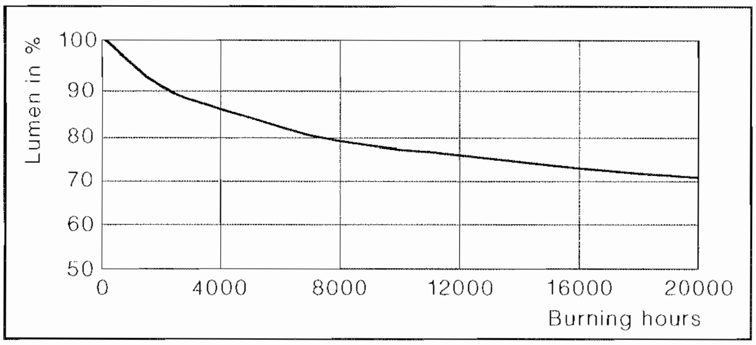


Lumen depreciation

FIGURE E2 TYPICAL LAMP MORTALITY/LUMEN DEPRECIATION DATA FOR METAL HALIDE CERAMIC LAMP



Lamp mortality



Lumen depreciation

FIGURE E3 TYPICAL LAMP MORTALITY/LUMEN DEPRECIATION DATA FOR METAL HALIDE QUARTZ LAMP

APPENDIX F

INDICATIVE LIGHTING LAYOUTS FOR SPECIFIC ROAD SITUATIONS

(Informative)

This Appendix sets out indicative lighting layouts for a number of specific road situations (see Figures F1 to F13). The luminaire spacings for the respective road elements should be determined on the basis of—

(a) luminance;

(b) illuminance; or

(c) both luminance and illuminance,

as specified in Section 3 of AS/NZS 1158.1.1. The design area that should be used for the determination of luminaire spacings from illuminance calculations is set out in AS/NZS 1158, Part 1.1.

Care should be taken to ensure the array of luminaires, seen from the perspective of the vehicle driver, does not present a misleading view of the course of the road ahead. See the example of a misleading array of luminaires in Figure F13.

LEGEND:

● = Lighting pole

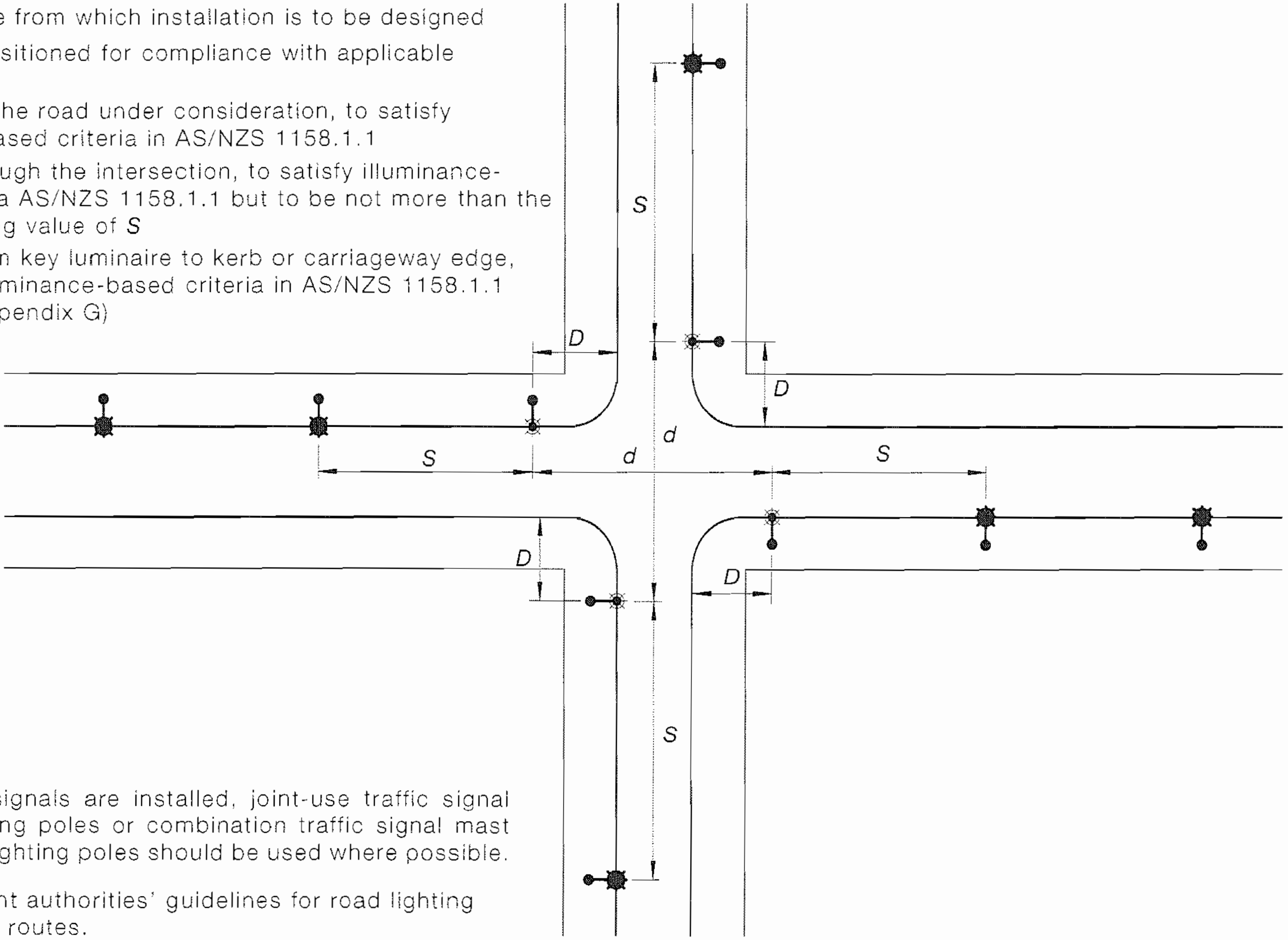
☼ = Key luminaire from which installation is to be designed

✹ = Luminaire positioned for compliance with applicable spacing, *S*

S = Spacing for the road under consideration, to satisfy luminance-based criteria in AS/NZS 1158.1.1

d = Spacing through the intersection, to satisfy illuminance-based criteria AS/NZS 1158.1.1 but to be not more than the corresponding value of *S*

D = Distance from key luminaire to kerb or carriageway edge, to satisfy illuminance-based criteria in AS/NZS 1158.1.1 (See also Appendix G)



NOTES:

1 Where traffic signals are installed, joint-use traffic signal and road lighting poles or combination traffic signal mast arm and road lighting poles should be used where possible.

2 Refer to relevant authorities' guidelines for road lighting poles on traffic routes.

FIGURE F1 INDICATIVE SINGLE-SIDED LAYOUT AT NON-CHANNELIZED FOUR-WAY INTERSECTION

LEGEND:

● = Lighting pole

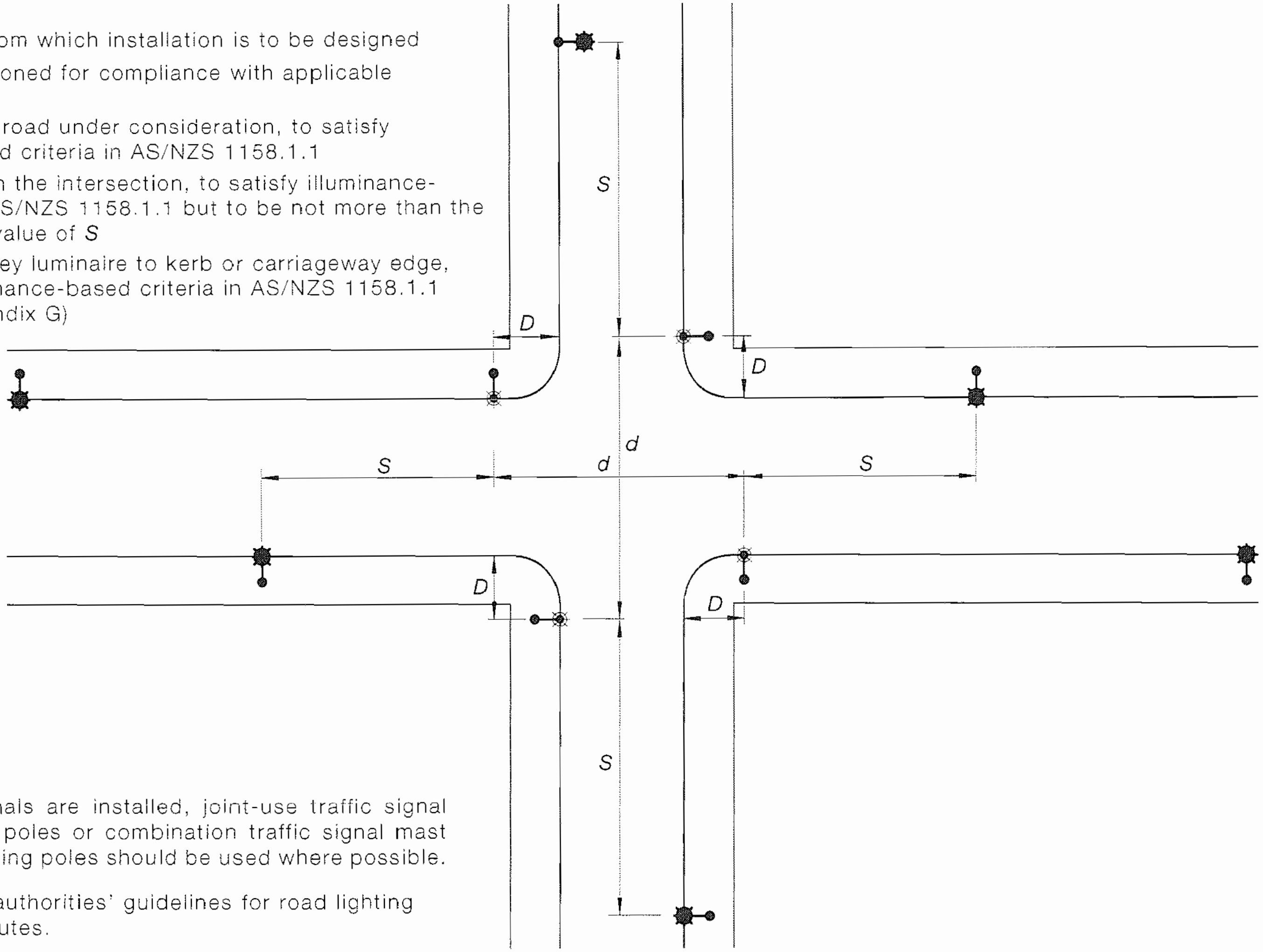
✳ = Key luminaire from which installation is to be designed

✹ = Luminaire positioned for compliance with applicable spacing, *S*

S = Spacing for the road under consideration, to satisfy luminance-based criteria in AS/NZS 1158.1.1

d = Spacing through the intersection, to satisfy illuminance-based criteria AS/NZS 1158.1.1 but to be not more than the corresponding value of *S*

D = Distance from key luminaire to kerb or carriageway edge, to satisfy illuminance-based criteria in AS/NZS 1158.1.1 (See also Appendix G)

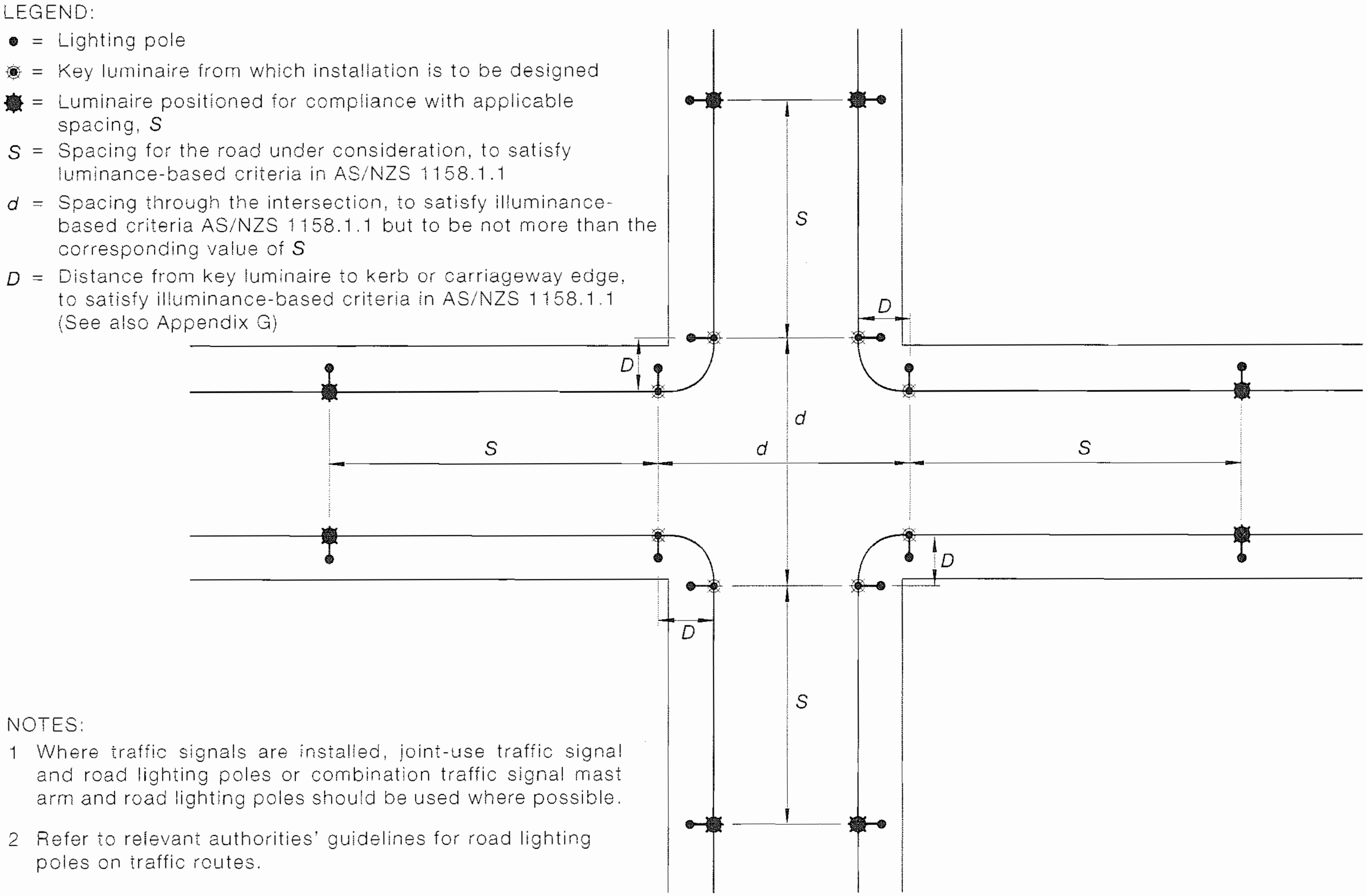


NOTES:

1 Where traffic signals are installed, joint-use traffic signal and road lighting poles or combination traffic signal mast arm and road lighting poles should be used where possible.

2 Refer to relevant authorities' guidelines for road lighting poles on traffic routes.

FIGURE F2 INDICATIVE STAGGERED LAYOUT AT NON-CHANNELIZED FOUR-WAY INTERSECTION



LEGEND:

● = Lighting pole

◉ = Key luminaire from which installation is to be designed

✸ = Luminaire positioned for compliance with applicable spacing, *S*

S = Spacing for the road under consideration, to satisfy luminance-based criteria in AS/NZS 1158.1.1

d = Spacing through the intersection, to satisfy illuminance-based criteria AS/NZS 1158.1.1 but to be not more than the corresponding value of *S*

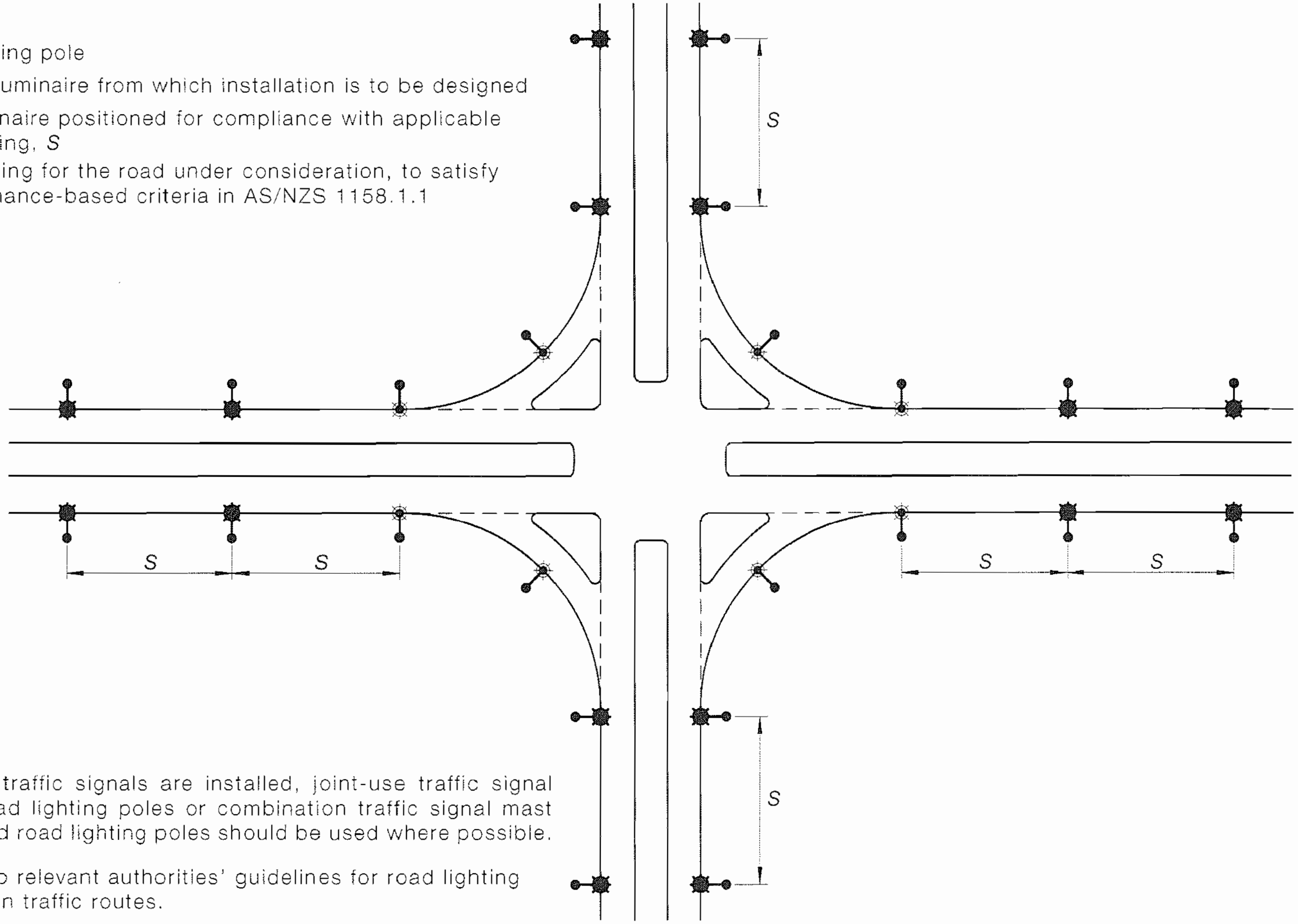
D = Distance from key luminaire to kerb or carriageway edge, to satisfy illuminance-based criteria in AS/NZS 1158.1.1 (See also Appendix G)

NOTES:

1 Where traffic signals are installed, joint-use traffic signal and road lighting poles or combination traffic signal mast arm and road lighting poles should be used where possible.

2 Refer to relevant authorities' guidelines for road lighting poles on traffic routes.

FIGURE F3 INDICATIVE OPPOSITE LAYOUT AT NON-CHANNELIZED FOUR-WAY INTERSECTION



LEGEND:

● = Lighting pole

✹ = Key luminaire from which installation is to be designed

✸ = Luminaire positioned for compliance with applicable spacing, *S*

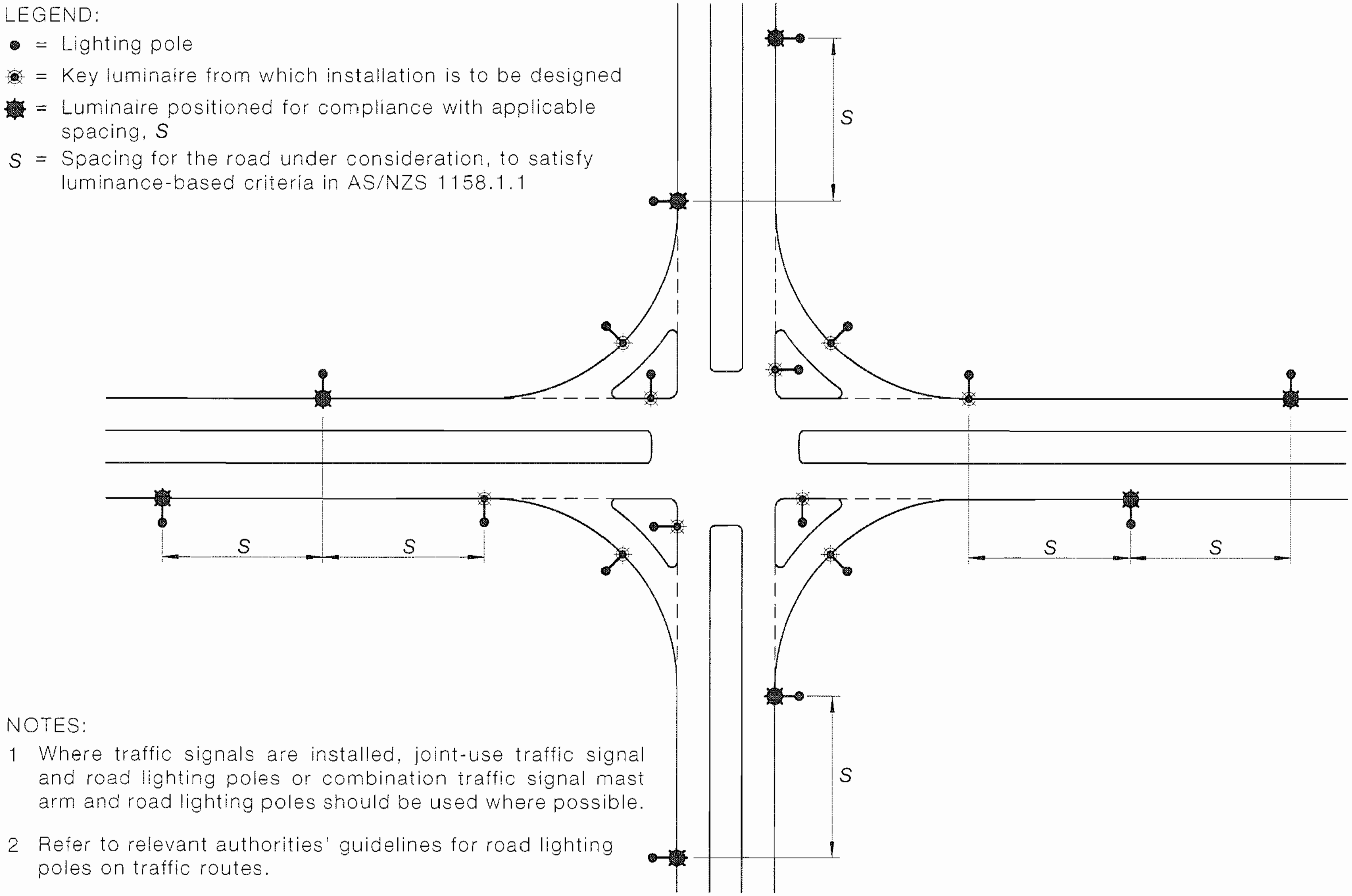
S = Spacing for the road under consideration, to satisfy luminance-based criteria in AS/NZS 1158.1.1

NOTES:

1 Where traffic signals are installed, joint-use traffic signal and road lighting poles or combination traffic signal mast arm and road lighting poles should be used where possible.

2 Refer to relevant authorities' guidelines for road lighting poles on traffic routes.

FIGURE F4 INDICATIVE OPPOSITE LAYOUT AT CHANNELIZED FOUR-WAY INTERSECTION



LEGEND:

● = Lighting pole

⊛ = Key luminaire from which installation is to be designed

✸ = Luminaire positioned for compliance with applicable spacing, *S*

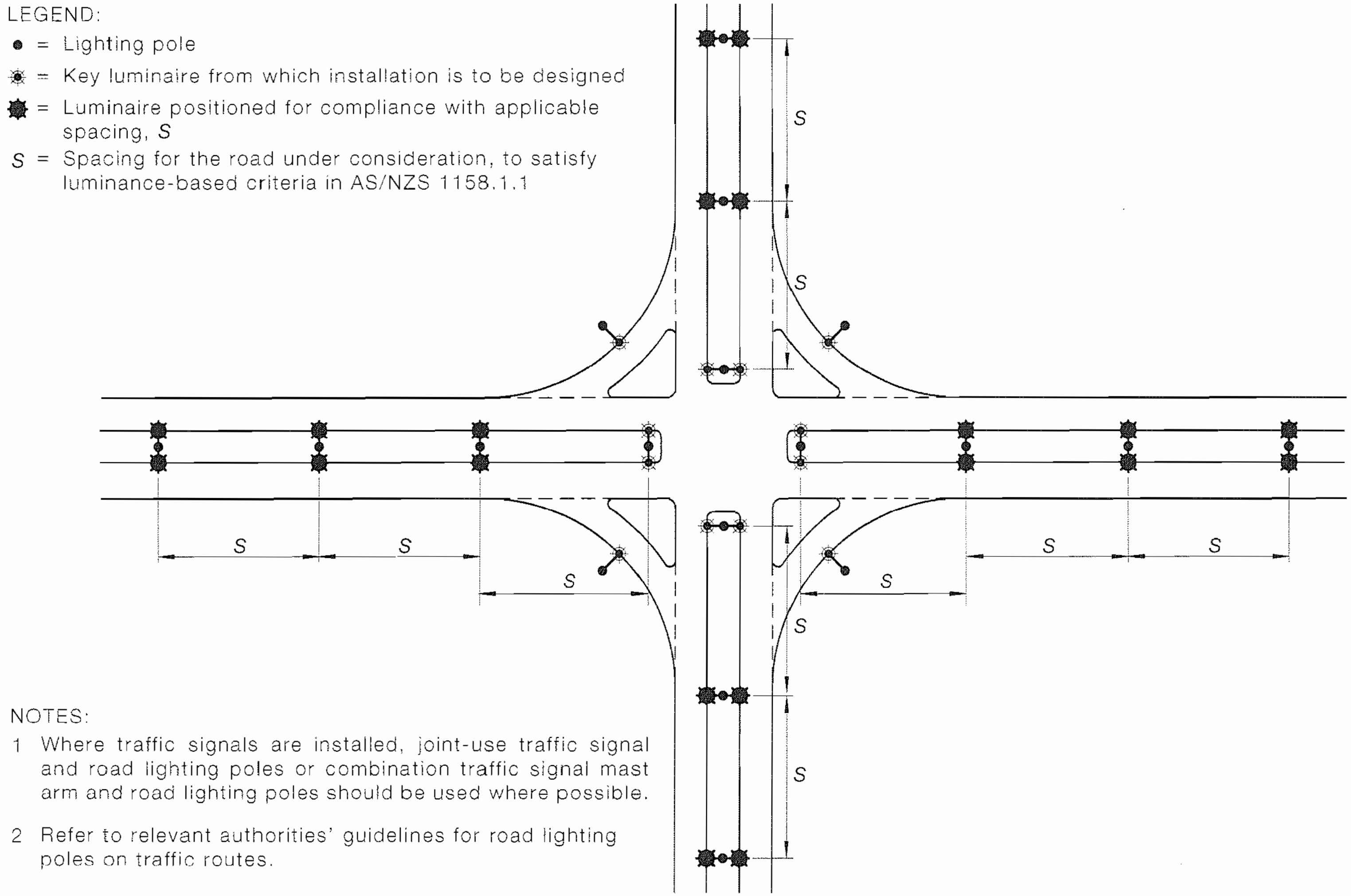
S = Spacing for the road under consideration, to satisfy luminance-based criteria in AS/NZS 1158.1.1

NOTES:

1 Where traffic signals are installed, joint-use traffic signal and road lighting poles or combination traffic signal mast arm and road lighting poles should be used where possible.

2 Refer to relevant authorities' guidelines for road lighting poles on traffic routes.

FIGURE F5 INDICATIVE STAGGERED LAYOUT AT CHANNELIZED FOUR-WAY INTERSECTION



LEGEND:

● = Lighting pole

✻ = Key luminaire from which installation is to be designed

✹ = Luminaire positioned for compliance with applicable spacing, *S*

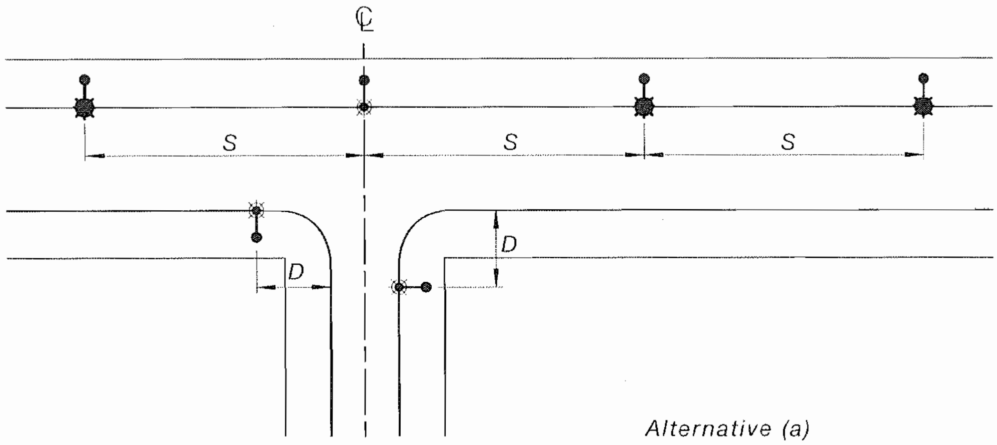
S = Spacing for the road under consideration, to satisfy luminance-based criteria in AS/NZS 1158.1.1

NOTES:

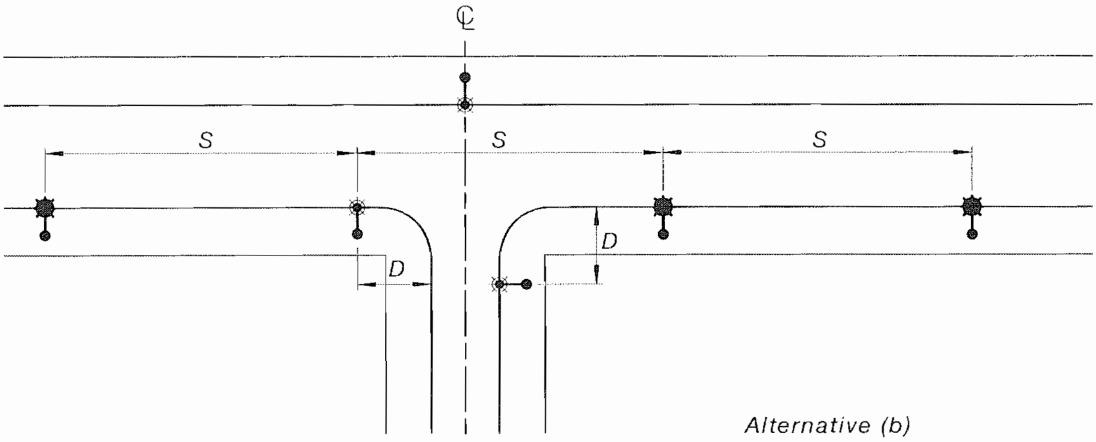
1 Where traffic signals are installed, joint-use traffic signal and road lighting poles or combination traffic signal mast arm and road lighting poles should be used where possible.

2 Refer to relevant authorities' guidelines for road lighting poles on traffic routes.

FIGURE F6 INDICATIVE CENTRAL LAYOUT AT CHANNELIZED FOUR-WAY INTERSECTION



Alternative (a)



Alternative (b)

LEGEND:

● = Lighting pole

⊛ = Key luminaire from which installation is to be designed

✹ = Luminaire positioned for compliance with applicable spacing, *S*

S = Spacing for the road under consideration, to satisfy luminance-based criteria in AS/NZS 1158.1.1

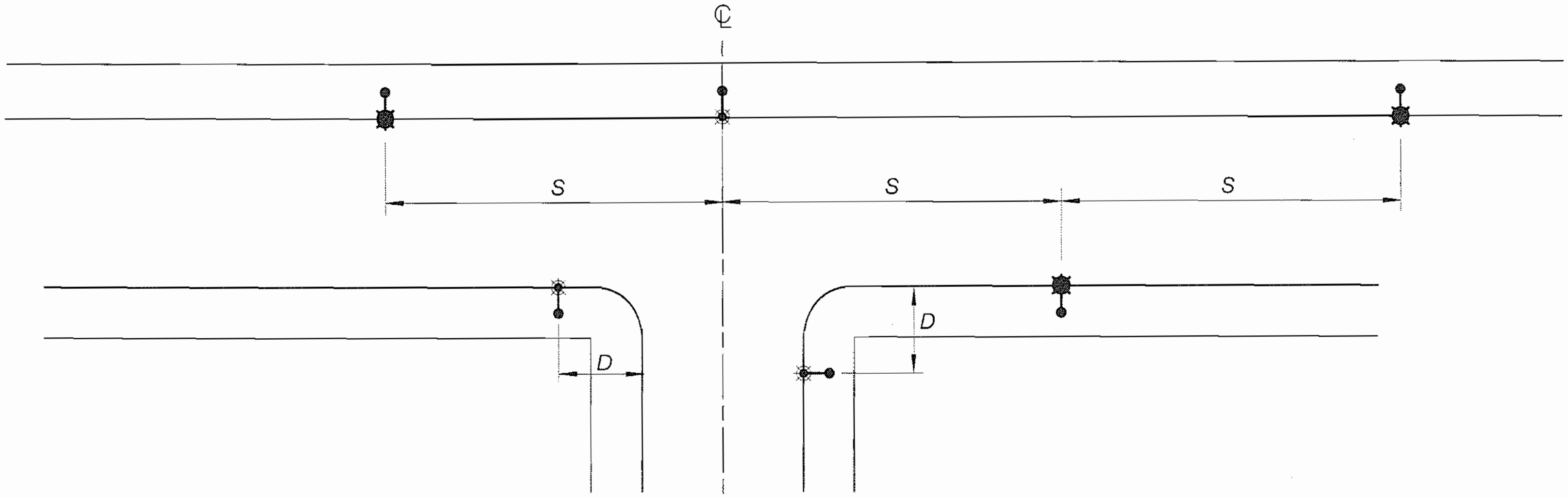
D = Distance from key luminaire to kerb or carriageway edge, to satisfy illuminance-based criteria in AS/NZS 1158.1.1 (See also Appendix G)

NOTES:

1 Where traffic signals are installed, joint-use traffic signal and road lighting poles or combination traffic signal mast arm and road lighting poles should be used where possible.

2 Refer to relevant authorities' guidelines for road lighting poles on traffic routes.

FIGURE F7 INDICATIVE SINGLE-SIDED LAYOUT AT NON-CHANNELIZED INTERSECTION



LEGEND:

● = Lighting pole

✸ = Key luminaire from which installation is to be designed

✹ = Luminaire positioned for compliance with applicable spacing, *S*

S = Spacing for the road under consideration, to satisfy luminance-based criteria in AS/NZS 1158.1.1

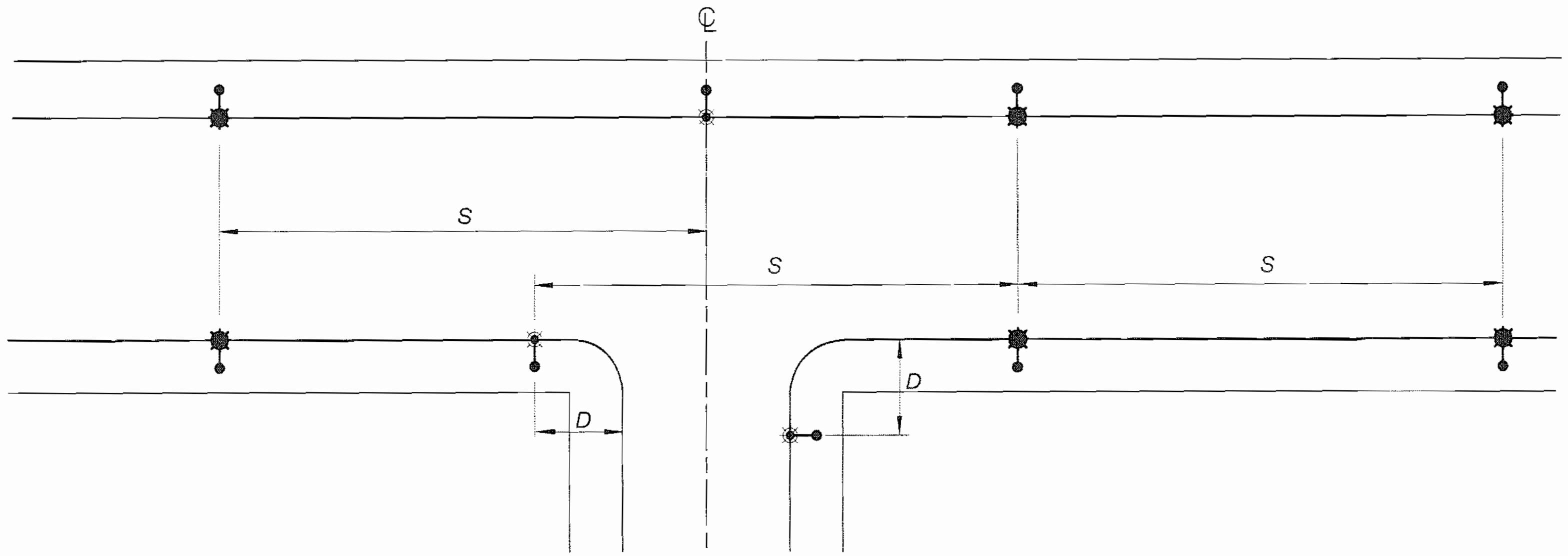
D = Distance from key luminaire to kerb or carriageway edge, to satisfy illuminance-based criteria in AS/NZS 1158.1.1 (See also Appendix G)

NOTES:

1 Where traffic signals are installed, joint-use traffic signal and road lighting poles or combination traffic signal mast arm and road lighting poles should be used where possible.

2 Refer to relevant authorities' guidelines for road lighting poles on traffic routes.

FIGURE F8 INDICATIVE STAGGERED LAYOUT AT NON-CHANNELIZED INTERSECTION



LEGEND:

● = Lighting pole

⊛ = Key luminaire from which installation is to be designed

✸ = Luminaire positioned for compliance with applicable spacing, *S*

S = Spacing for the road under consideration, to satisfy luminance-based criteria in AS/NZS 1158.1.1

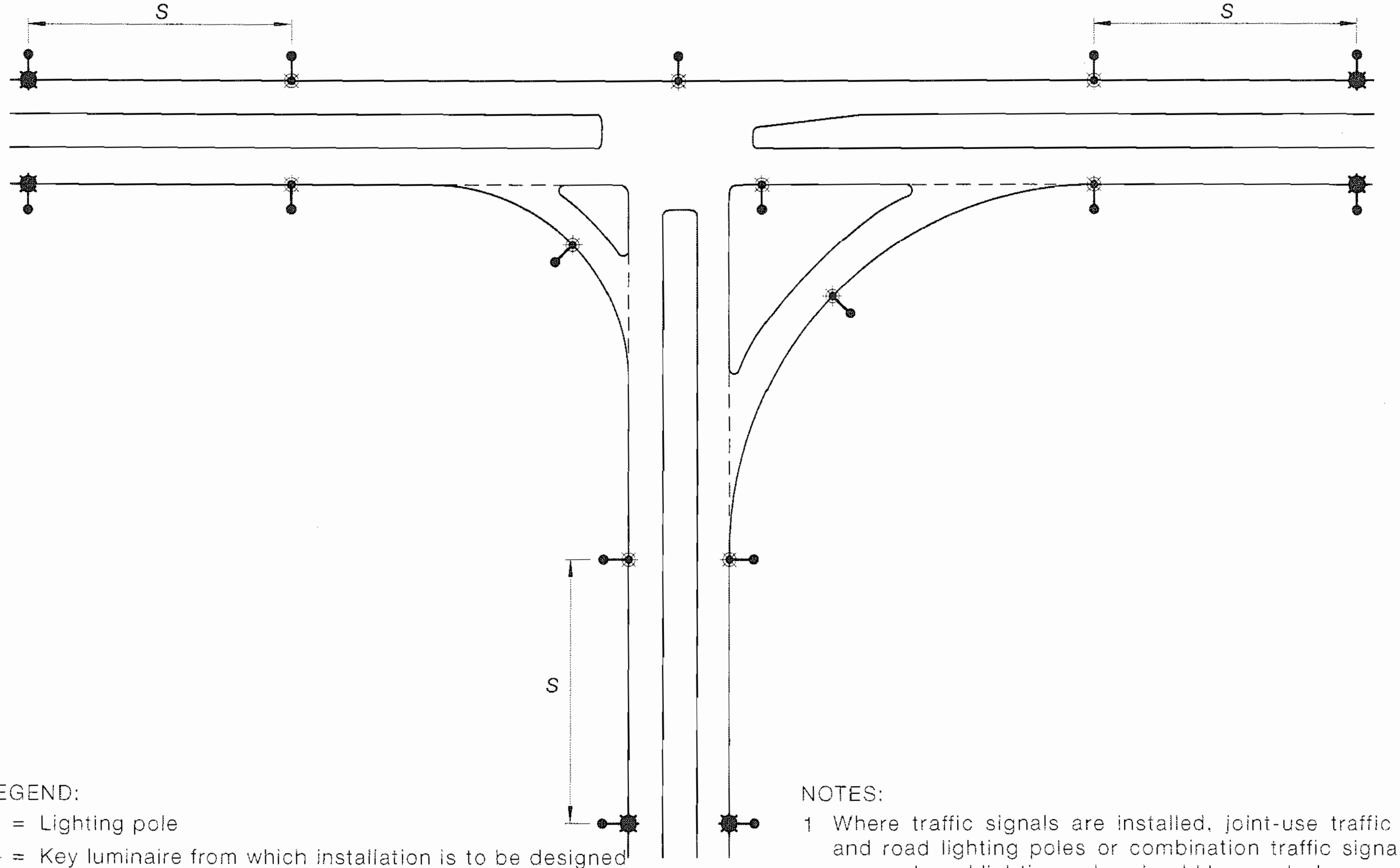
D = Distance from key luminaire to kerb or carriageway edge, to satisfy illuminance-based criteria in AS/NZS 1158.1.1 (See also Appendix G)

NOTES:

1 Where traffic signals are installed, joint-use traffic signal and road lighting poles or combination traffic signal mast arm and road lighting poles should be used where possible.

2 Refer to relevant authorities' guidelines for road lighting poles on traffic routes.

FIGURE F9 INDICATIVE OPPOSITE LAYOUT AT NON-CHANNELIZED INTERSECTION



LEGEND:

● = Lighting pole

⊛ = Key luminaire from which installation is to be designed

✹ = Luminaire positioned for compliance with applicable spacing, *S*

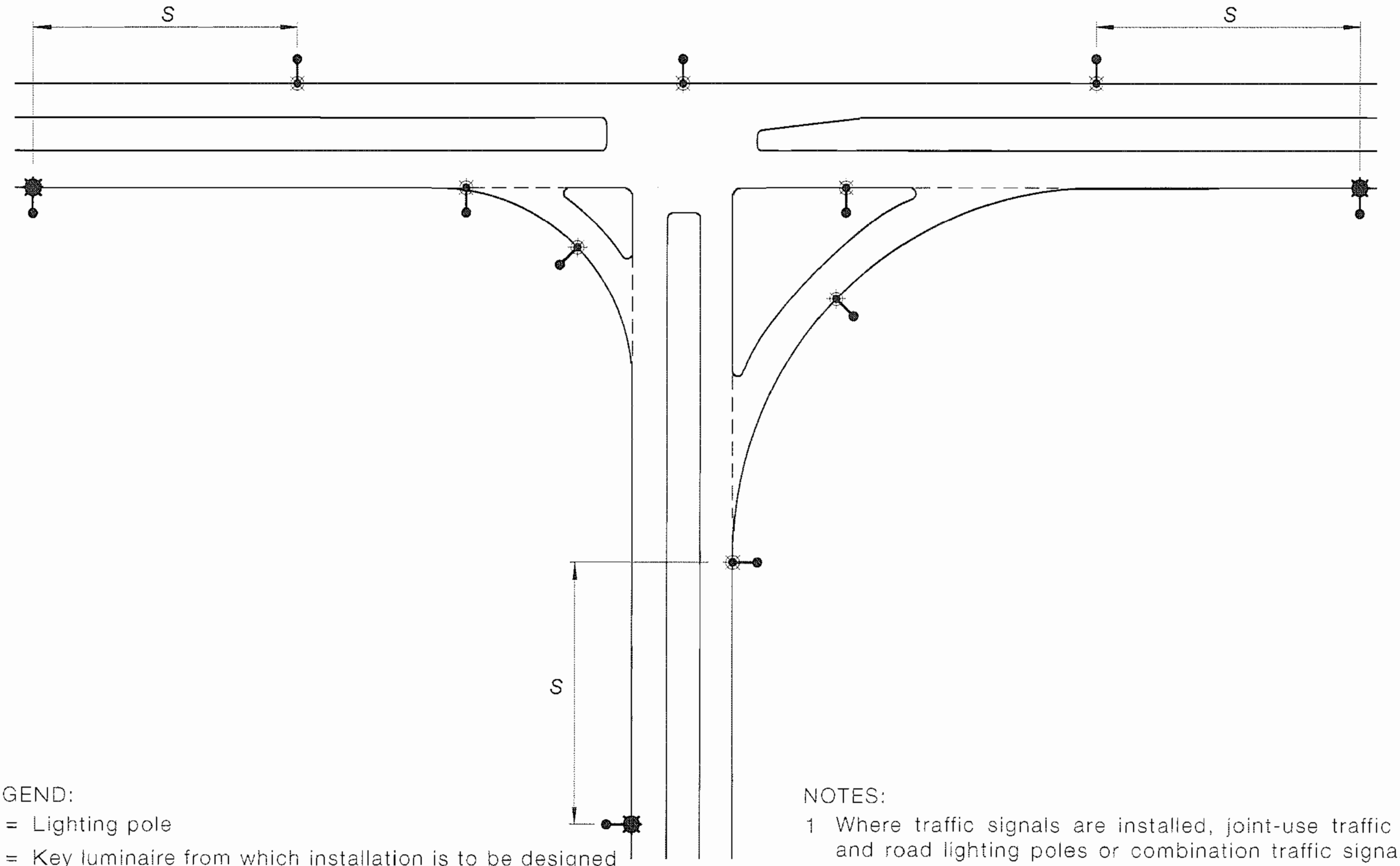
S = Spacing for the road under consideration, to satisfy luminance-based criteria in AS/NZS 1158.1.1

NOTES:

1 Where traffic signals are installed, joint-use traffic signal and road lighting poles or combination traffic signal mast arm and road lighting poles should be used where possible.

2 Refer to relevant authorities' guidelines for road lighting poles on traffic routes.

FIGURE F10 INDICATIVE OPPOSITE LAYOUT AT CHANNELIZED INTERSECTION



LEGEND:

● = Lighting pole

◉ = Key luminaire from which installation is to be designed

✹ = Luminaire positioned for compliance with applicable spacing, *S*

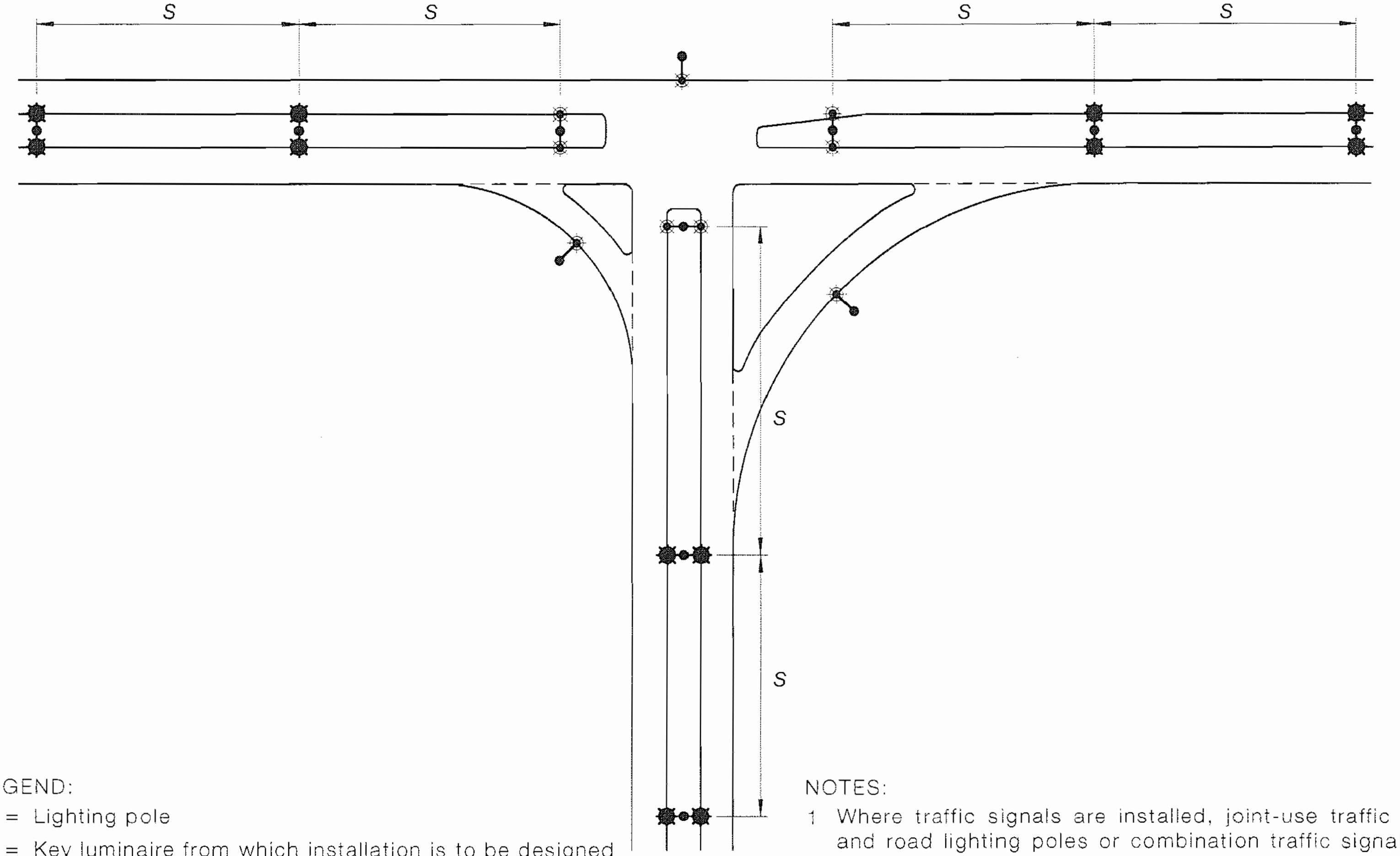
S = Spacing for the road under consideration, to satisfy luminance-based criteria in AS/NZS 1158.1.1

NOTES:

1 Where traffic signals are installed, joint-use traffic signal and road lighting poles or combination traffic signal mast arm and road lighting poles should be used where possible.

2 Refer to relevant authorities' guidelines for road lighting poles on traffic routes.

FIGURE F11 INDICATIVE STAGGERED LAYOUT AT CHANNELIZED INTERSECTION



LEGEND:

● = Lighting pole

⊛ = Key luminaire from which installation is to be designed

✹ = Luminaire positioned for compliance with applicable spacing, *S*

S = Spacing for the road under consideration, to satisfy luminance-based criteria in AS/NZS 1158.1.1

NOTES:

1 Where traffic signals are installed, joint-use traffic signal and road lighting poles or combination traffic signal mast arm and road lighting poles should be used where possible.

2 Refer to relevant authorities' guidelines for road lighting poles on traffic routes.

FIGURE F12 INDICATIVE CENTRAL LAYOUT AT CHANNELIZED INTERSECTION

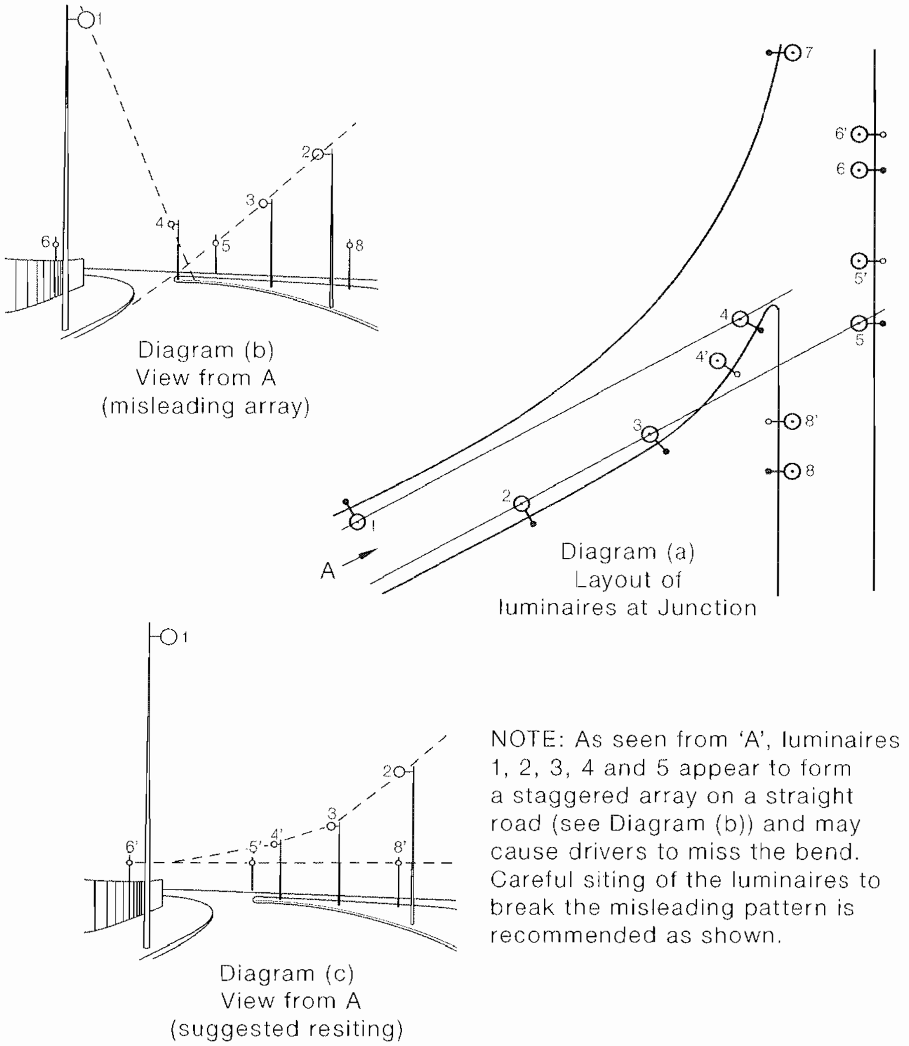


Diagram (b)
View from A
(misleading array)

Diagram (a)
Layout of
luminaires at Junction

Diagram (c)
View from A
(suggested resiting)

NOTE: As seen from 'A', luminaires 1, 2, 3, 4 and 5 appear to form a staggered array on a straight road (see Diagram (b)) and may cause drivers to miss the bend. Careful siting of the luminaires to break the misleading pattern is recommended as shown.

FIGURE F13 MISLEADING ARRAY OF LUMINAIRES AT CONVERGING TRAFFIC STREAMS

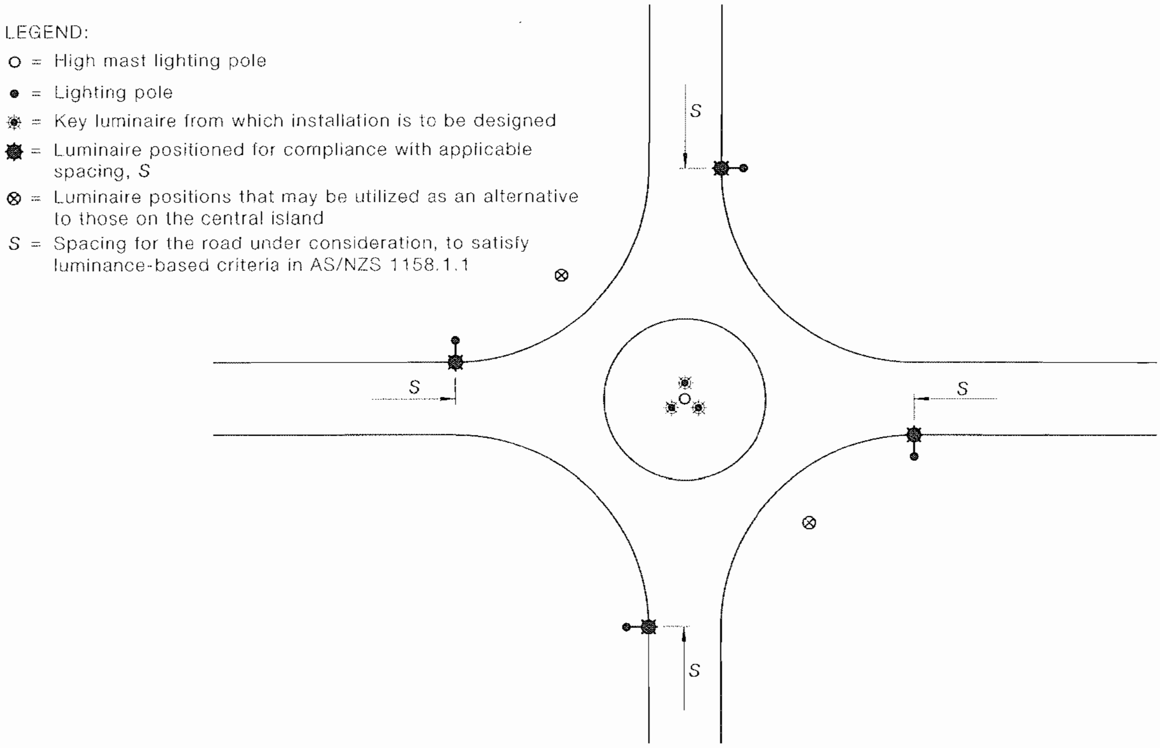

LEGEND:
○ = High mast lighting pole
● = Lighting pole
✷ = Key luminaire from which installation is to be designed
✹ = Luminaire positioned for compliance with applicable spacing, S
⊗ = Luminaire positions that may be utilized as an alternative to those on the central island
S = Spacing for the road under consideration, to satisfy luminance-based criteria in AS/NZS 1158.1.1
S
S
S
S

FIGURE F14 INDICATIVE LAYOUT AT ROUNDABOUTS OF DIAMETER BETWEEN 6 M AND 40 M

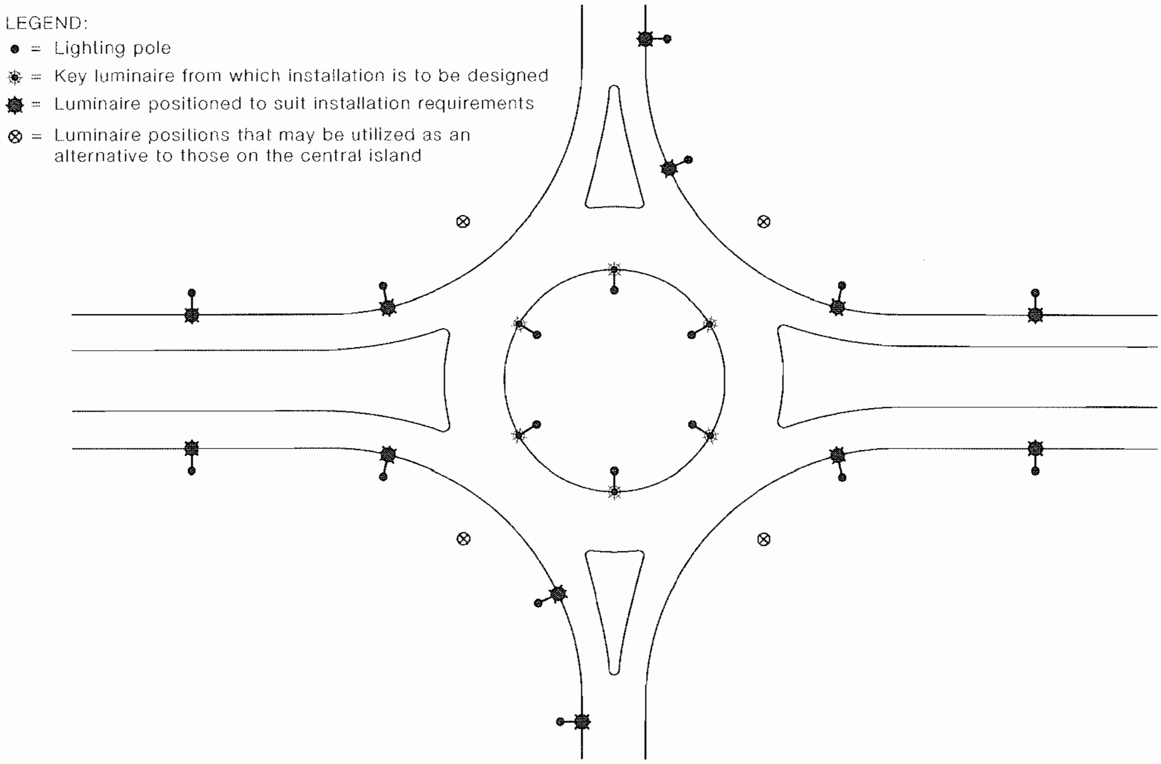

LEGEND:
● = Lighting pole
✷ = Key luminaire from which installation is to be designed
✹ = Luminaire positioned to suit installation requirements
⊗ = Luminaire positions that may be utilized as an alternative to those on the central island

FIGURE F15 INDICATIVE LAYOUT AT ROUNDABOUTS OF DIAMETER OF GREATER THAN 60 M

NOTES

NOTES

Standards Australia

Standards Australia is an independent company, limited by guarantee, which prepares and publishes most of the voluntary technical and commercial standards used in Australia. These standards are developed through an open process of consultation and consensus, in which all interested parties are invited to participate. Through a Memorandum of Understanding with the Commonwealth government, Standards Australia is recognized as Australia's peak national standards body.

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The first national Standards organization was created in New Zealand in 1932. The Standards Council of New Zealand is the national authority responsible for the production of Standards. Standards New Zealand is the trading arm of the Standards Council established under the Standards Act 1988.

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Under a Memorandum of Understanding between Standards Australia and Standards New Zealand, Australian/New Zealand Standards are prepared by committees of experts from industry, governments, consumers and other sectors. The requirements or recommendations contained in published Standards are a consensus of the views of representative interests and also take account of comments received from other sources. They reflect the latest scientific and industry experience. Australian/New Zealand Standards are kept under continuous review after publication and are updated regularly to take account of changing technology.

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Standards Australia and Standards New Zealand are responsible for ensuring that the Australian and New Zealand viewpoints are considered in the formulation of international Standards and that the latest international experience is incorporated in national and Joint Standards. This role is vital in assisting local industry to compete in international markets. Both organizations are the national members of ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission).

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